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ABSTRACT

The Foundational Approaches in Science Teaching (FAST) project, which began under the sponsorship of the Hawaii Science Curriculum Council, contains a series of interdisciplinary science courses that emphasize the foundational concepts and methods of the physical, biological, and earth sciences. By directly involving students in investigating events in their everyday environment and carrying out experiments to answer some of their questions, FAST courses give students a sense of how the modern scientific community operates. This instructional guide presents a background of the FAST program and its conceptual framework. It presents information on classroom organization and management when using the FAST program and information on facilitating group discussions. At the time of this writing, over 500,000 students have taken one or more years of the program. Some of the material has been translated into Lao, Ilokano, and Japanese. FAST 1 is also available in Braille. (PR)

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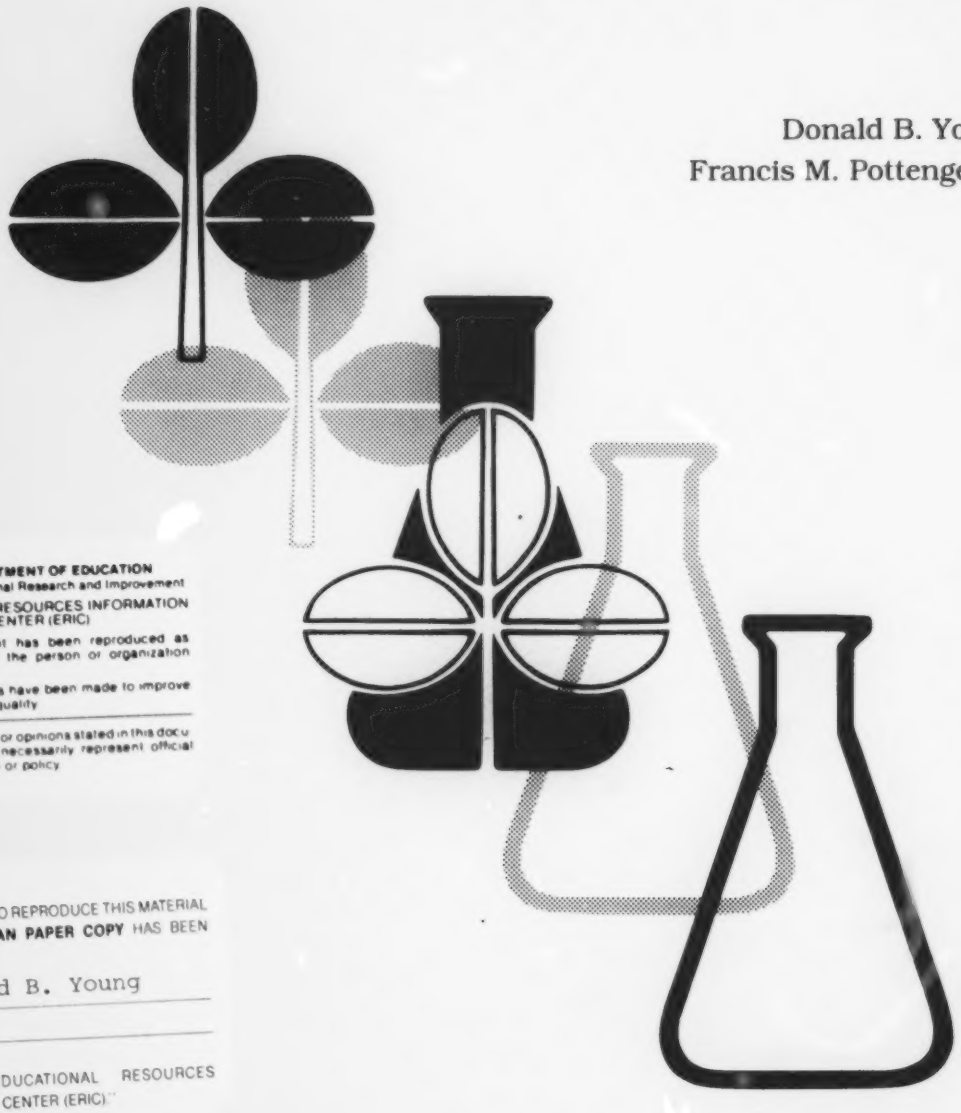
Instructional Guide

FAST, Foundational Approaches in Science Teaching

Second Edition



Donald B. Young
Francis M. Pottenger III

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Instructional Guide

FAST, Foundational Approaches in Science Teaching

Second Edition

Donald B. Young
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4

CONTENTS

ACKNOWLEDGMENTS iv

PREFACE v

INTRODUCTION 1
- History 1
- Curricular and Instructional Assumptions 1
- Theory and Practice 2
- Objectives 3
- Curriculum Design 5
- Instructional Mode 7
- Instructional Model 8

CONCEPTUAL FRAMEWORK 9
- *The Local Environment* 9
- *The Flow of Matter and Energy Through the Biosphere* 15
- *Change over Time* 18

INSTRUCTIONAL MATERIALS 21
- Student Materials/Teacher Materials 21
- Support Design and *FAST* Materials 24
- Instructional Materials Format 25

CLASSROOM ORGANIZATION AND MANAGEMENT 30
- The *FAST* Teacher/The *FAST* Student 30
- Suggestions for Using the Program 31
- The Student Notebook 34
- Planning for Effective Group Interaction 36
- Facilitating Group Discussion 56

ACKNOWLEDGMENTS

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PREFACE

The Foundational Approaches in Science Teaching (*FAST*) program is one of several curriculum development projects of the Curriculum Research & Development Group (CRDG) of the University of Hawaii. CRDG is a branch of the College of Education. The CRDG staff of about a hundred members conducts curriculum research and design, develops and evaluates educational materials, disseminates them, and offers training and follow-up services. CRDG programs serve children and youth at preschool, elementary-school, middle-school, and high-school levels. Its programs are tested and used in the University Laboratory School, in the schools of Hawaii, in selected schools in the Pacific Basin, and in the United States generally.

Members of the *FAST* staff have developed a series of interdisciplinary science courses that emphasize the foundational concepts and methods of the physical, biological, and earth sciences. By directly involving students in investigating events in their everyday environment and carrying out experiments to answer some of their questions, *FAST* courses give students a sense of how the modern scientific community operates. This process of inquiry and subsequent research is used throughout each course.

Students in *FAST* courses study several disciplines, including physics, chemistry, earth science, and biology. In addition, *FAST* includes study of the interrelationships among science, technology, and society in a component called the Relational Study. Thus, through an inquiry approach, these courses give students an understanding of both the concepts of science and their applications to the everyday environment.

Titles of the courses developed thus far are *The Local Environment*, *The Flow of Matter and Energy Through the Biosphere*, and *Change over Time*.

INTRODUCTION

HISTORY

The *FAST* program was begun under the sponsorship of the Hawaii Science Curriculum Council. This council was formed in October 1966 in response to the recommendations of a curriculum conference conducted by the Hawaii Curriculum Center for the Department of Education in June of that year. The Council was composed of teachers and science supervisory personnel from the public and private schools of Hawaii, members of the College of Arts and Sciences and the College of Education of the University of Hawaii, and representatives of industry.

A survey of available and emerging science curricula indicated that a bridging program was needed at the intermediate level to ease students' transition from the general process programs of the elementary schools to the disciplinary programs of the high schools. A broad outline for such a bridging program was completed in February 1967. Development of *FAST* began in the summer of 1967 and continues under the aegis of the Curriculum Research & Development Group of the University of Hawaii.

Since its first pilot trials in 1970, an ever-expanding number of teachers and students have participated in the program. At the time of this writing, over 500,000 students have taken one or more years of the program. Some of the materials have been translated into Lao, Ilokano, and Japanese. *FAST 1* is also available in Braille.

CURRICULAR AND INSTRUCTIONAL ASSUMPTIONS

The *FAST* program is designed to prepare students to participate in the transactions of a dynamic society based on science and technology. The guiding assumptions of *FAST* have been drawn from the work of Arthur R. King, Jr., and John A. Brownell.[1]

First, we assume that the primary purpose of schooling is to develop each student's intellectual capacities. It is through development of the intellect that one satisfies the inherent need to know, expands one's options for independent thought and action, and enhances one's capabilities for meeting the demands of career and citizenship in a changing society.

Second, the intellectual activity of greatest import to our society has grown out of the endeavors that characterize the applied and theoretic disciplines—science, mathematics, engineering, jurisprudence, sociology, political science, theology, and so on—that shape our society. Understanding the structures of the disciplines is essential to understanding our society's past, present, and future.

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[1]King, Arthur R., Jr., and Brownell, John A. 1966. The Curriculum and the Disciplines of Knowledge. J. Wiley & Sons.

Third, the disciplines are uniquely structured for instruction. The knowledge they have produced and their ways of generating new knowledge have been intentionally crafted for transmission from one generation to the next. Mathematics, engineering, and astronomy, for example, have histories of successful transmission reaching back at least 100 generations.

For these reasons, the curriculum should authentically reflect the structure of the disciplines and use their instructional means for expanding the intellect. Using the disciplines of science as the model for curriculum provides subject matter of proven interest and worth as well as an instructional mode of proven success. The time-honored mode of instruction in the disciplines of science consists of generating, warranting, and applying knowledge under the guidance of a person knowledgeable in the disciplines.

It follows that students must experience the joys and frustrations of advancing and testing hypotheses and submitting their work for peer critique. They must understand that error and misdirection are normal steps in successful prediction and replication and that a well-formulated, well-supported hypothesis accepted by the scientific community is a tentative product of the community's judgment. To capture the nature of scientific research and collaboration, student-teacher roles must reflect an interactive leader-colleague relationship rather than a passive authority-audience relationship.

THEORY AND PRACTICE

FAST is based on a constructivist philosophy of learning. Among the constructivist assumptions are the beliefs that all learners construct their own knowledge and understanding from their experiences, that this knowledge development is incremental, and that the knowledge we hold in common is developed and clarified through interactions with others.

Translated into classroom practice, these beliefs mean that students in *FAST* engage in experiential, hands-on learning. Investigations are carefully sequenced and connected to previous experience both in school and out of school to enable students to build their knowledge. Further, *FAST* investigations are conducted in small collaborative groups who share data, ideas, and experiences. Class discussion following each investigation is essential to identify and clarify generalizations held in common.

A research team model is used for class organization in *FAST*. Group interaction in planning and executing investigations, discussing and validating hypotheses, and summarizing and drawing conclusions is central to the *FAST* instructional system. Instead of a disseminator of information, the teacher becomes a facilitator of group interaction and director of learning, maintaining an atmosphere of challenge, setting tasks, asking questions, giving suggestions for further investigations, and helping students evaluate their work and their competences. In many *FAST* sequences, students engage in the full scope of research activities. They must identify the kind

of problem they are dealing with, formulate hypotheses, conduct experiments, and report their findings for critical review by their peers. Thus students become producers rather than receivers of information.

OBJECTIVES

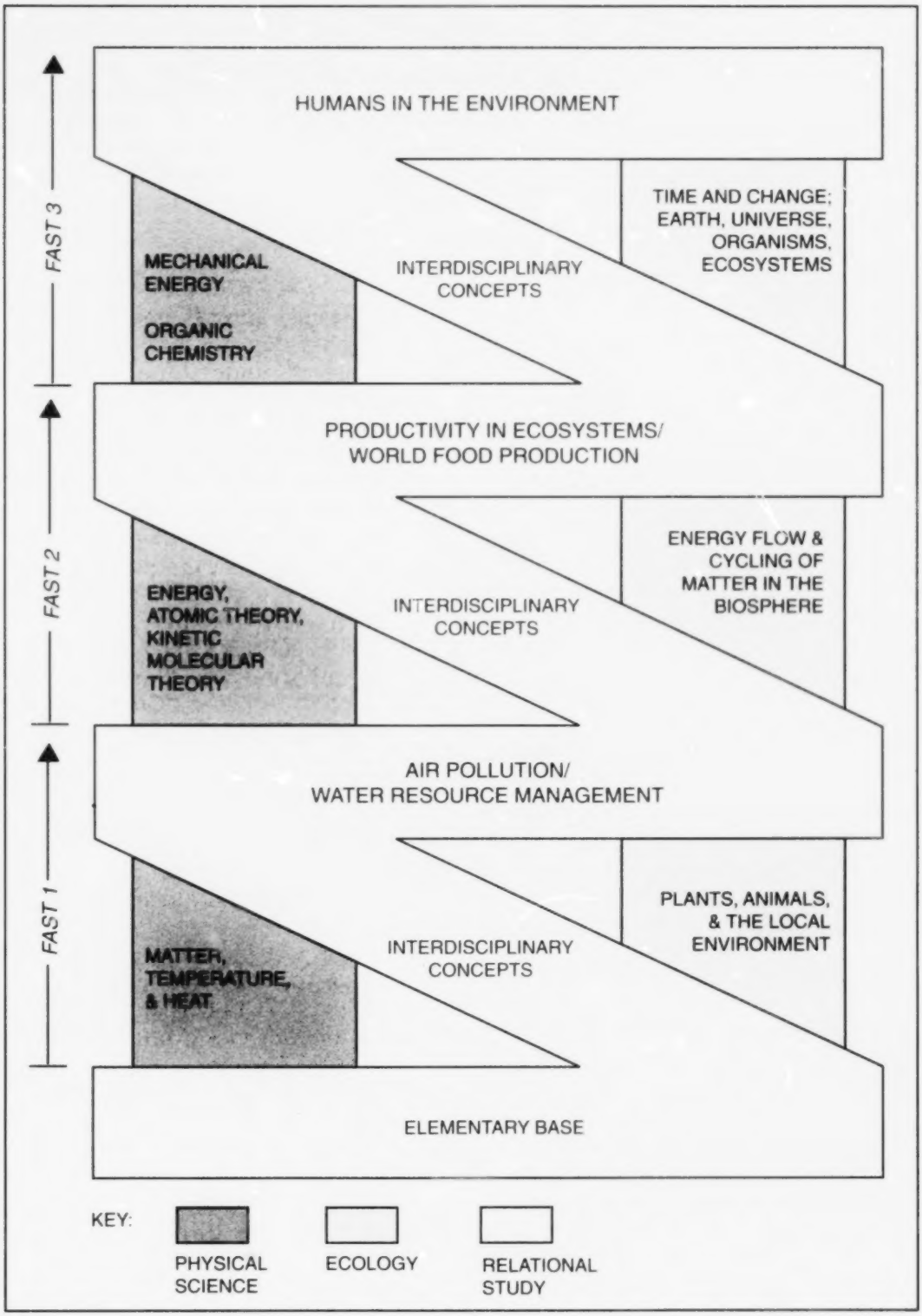
FAST is designed to provide investigative experiences and inquiry activities in the physical, biological, and earth sciences as well as in the application of the knowledge of these sciences to environmental issues.

The goal of *FAST* is to develop scientifically literate students who have both the background necessary for understanding environmental concerns in our technological society and the foundational tools for further study in science.

The objectives of *FAST* are to increase students'

1. capability to perform basic laboratory skills.
2. capability to use the symbolic tools employed in science.
3. knowledge of concepts that are foundational to modern science.
4. capability to engage in scientific inquiry.
5. understanding of the sequential nature of the development of science.
6. understanding of the relationships among disciplines of science.
7. knowledge of the nature of science.
8. capability to apply scientific knowledge to other areas of endeavor.
9. understanding of the relationships among science, technology, and society.
10. capability to use scientific knowledge for making decisions.
11. internalization of the values, attitudes, and traits necessary for successful endeavor in science.

General Structure of the *FAST* Program



CURRICULUM DESIGN

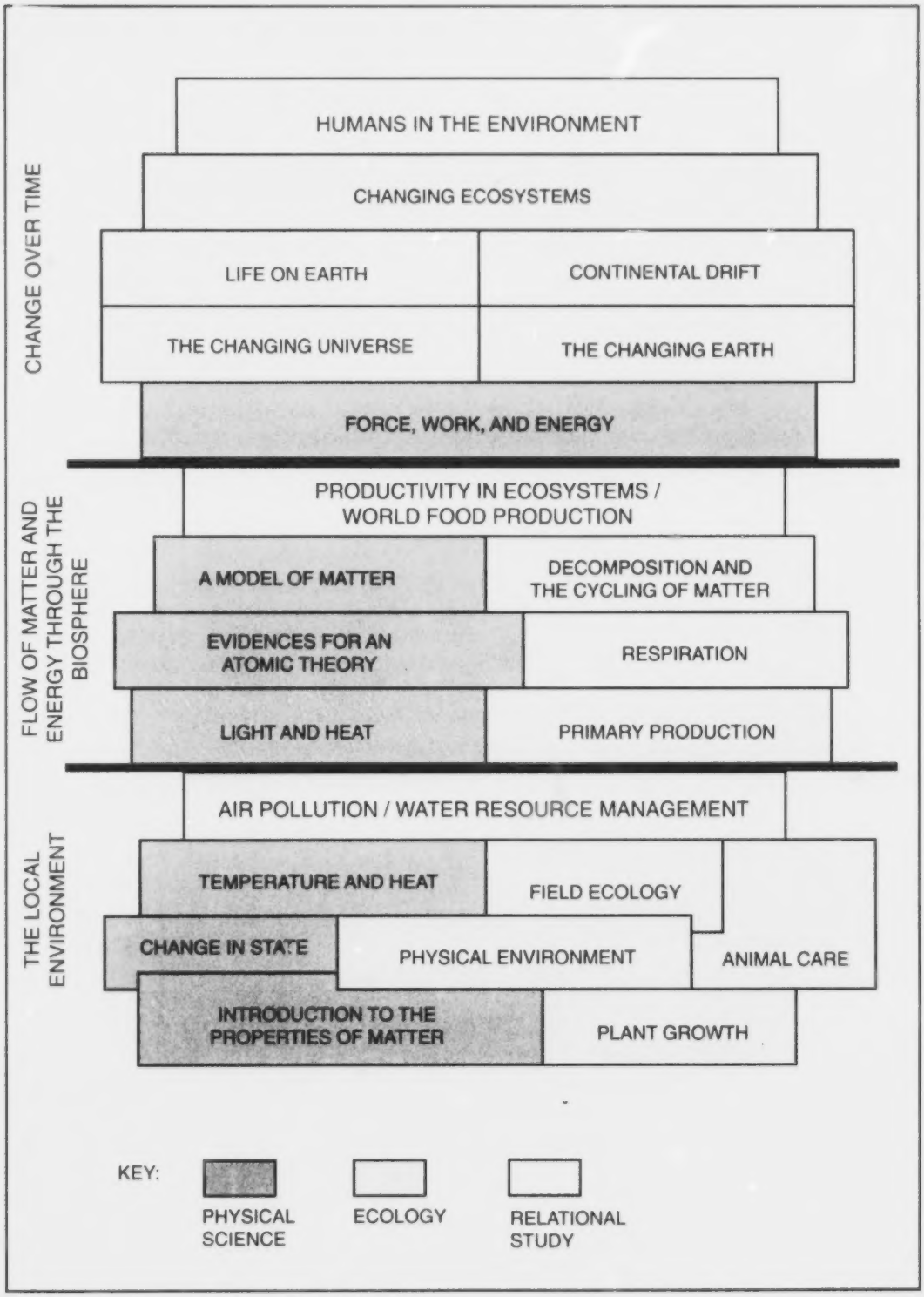
In the *FAST* program, several sciences, including chemistry, physics, earth science, and biology, are studied independently and are then brought together in the study of the ecology of the local environment. Throughout the program, the integrity of each of the disciplines is maintained. The subject matter of the program is organized into three strands—Physical Science, Ecology, and Relational Study. The first two strands provide the formal science content; the Relational Study strand integrates the sciences, technology, and society. The diagram on the previous page shows the general structure of the program.

Scientific content has been selected for interdisciplinary utility and social relevance. Principles developed in the Physical Science strand constitute the foundations of science and undergird the Ecology strand. The biological and earth science content of the Ecology strand is basic to understanding major environmental issues. The Relational Study strand uses the teaching strategy of reinforcing basic concepts through interdisciplinary work. That is, concepts and skills developed in one science are used or applied in another, thus linking all areas of science. The Relational Study strand also confronts students with the problem of how technologists, social planners, and citizens can use scientific knowledge in making decisions affecting environmental quality. See the content diagram on the following page.

The content of the Relational Study is drawn from the philosophy and history of science. It weaves the many parts of science into a meaningful whole. The Relational Study points out the inherent similarities and differences in the kinds of inquiry characteristic of ecology and physical science. It focuses on the historical parallels between work developed in the *FAST* laboratory and work done by the investigators who first grappled with the same concepts. It shows the connections between the sciences, the technologies, and the everyday world of citizens. It also exposes the limitations of scientific knowledge in the arena of social decision. Through this approach, students see scientific knowledge as but one of many factors (moral, ethical, aesthetic, political, etc.) that must be weighed in making decisions affecting society.

FAST provides common foundational experiences in the concepts and methods of science for students in the middle grades and the first year or two of high school. Special provisions are made for students of lower and higher ability levels. *FAST* has been crafted to capitalize on the unique developmental characteristics of adolescents. Students at this age show an increasing capability for abstract thinking; they can inquire into and reflect on the significance of their activities. This is also a time of commitment, when attitudes, habits, and intellectual styles that will strongly influence the remainder of their schooling and adulthood solidify. *FAST* seeks to help students develop positive attitudes toward science and useful problem-solving approaches by providing them with a variety of activities relevant to the world unfolding before them.

FAST Unit Diagram



INSTRUCTIONAL MODE

In its commitment to modeling the experience of practicing scientists, *FAST* relies on students working in research teams to generate the theoretical content of the program. The mechanism for ensuring continuity in the development of theoretic concepts is a carefully planned programmatic sequence of tasks and contexts of inquiry. Such planned encounters allow time to define categories of events, generate hypotheses, test hypotheses, correct misconceptions, and, ultimately, come to a consensus on the adequacy of explanations.

To achieve successful group generation of an acceptable conceptual structure, between 70% and 80% of the students' time is spent at the laboratory bench or in field studies. The remainder is devoted to data analysis, small group or class discussion, literature research, and report writing.

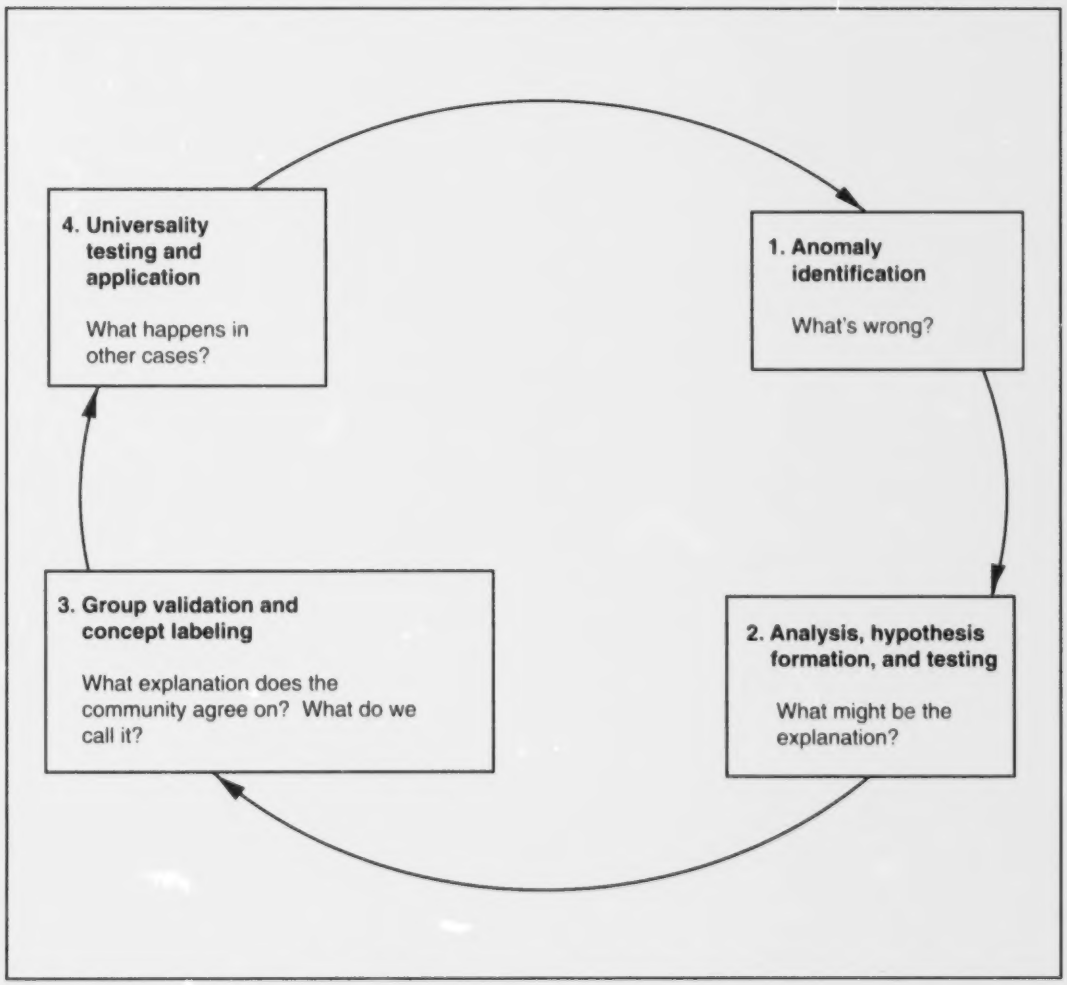
The teacher in *FAST* becomes a research director, a colleague who stimulates and facilitates ever deeper probing into problems. Students become researchers who create hypotheses, do physical experiments, organize and analyze data, and develop a team consensus on conclusions upon which study will progress.

The *FAST* research team approach can tolerate misconception because the contexts of investigation are carefully sequenced so that hypotheses and conclusions once developed are constantly retested. In *FAST*, students learn that science proceeds through a process of constant reconstruction of explanation in the light of new findings. Even as explanatory theory changes, these foundational concepts remain intact, forming the building blocks of the present scientific enterprise. As counterweight to the dynamics of theoretic evolution and revolution, foundational concepts of science once defined are seen to generally remain intact. Out of these foundational concepts has come the building of our present scientific enterprise.

INSTRUCTIONAL MODEL

FAST activities use a generalized instructional model based on normal research practices of science. In *FAST* the cycle begins with an activity that presents an anomaly—a puzzling situation—to engage students' curiosity and motivate inquiry. Next come opportunities for students to analyze the anomaly, develop an explanatory hypothesis, and test it. Successful hypotheses are validated in the class community, and new concepts are named. Finally students investigate the universality of the accepted explanation by testing it in applications. Often this sequence starts a new cycle of anomaly identification and further explanation.

FAST Instructional Model


4. Universality testing and application
What happens in other cases?
1. Anomaly identification
What's wrong?
3. Group validation and concept labeling
What explanation does the community agree on? What do we call it?
2. Analysis, hypothesis formation, and testing
What might be the explanation?

CONCEPTUAL FRAMEWORK

THE LOCAL ENVIRONMENT (FAST 1)

The unifying theme of *FAST 1* is the local environment. To gain understanding of their own environment, students conduct laboratory and field investigations to identify its components—plants, animals, and physical factors—focusing on interrelationships among them. They do laboratory activities to find explanations of the physical factors.

Work in the laboratory and field capitalizes on the excitement of discovery and engages students in activities characteristic of a modern scientific community. Investigation requires careful attention to planning, executing, and interpreting experiments and community validation of results.

In the Physical Science strand, students first investigate basic concepts of science, including mass, volume, and density, as well as the relationships between density and buoyancy. In so doing, they work with all three states of matter—solids, liquids, and gases—and use their knowledge to explain everyday phenomena. By the end of the first unit, they can define matter as having mass and volume and the derived property of density, and they know that matter exists in three states. It is here that students also begin to learn basic laboratory skills.

Next they investigate the melting, freezing, boiling, and condensing of pure substances and mixtures and use their knowledge of change of state to identify unknown substances. They also conduct experiments on fluid mechanics—the capacity of gases and liquids to transmit pressure and to be compressed or attenuated. They measure vapor pressure using student-made manometers and refine their definitions of *change of state* by considering the effects of pressure.

Throughout their investigations of buoyancy and density and change of state, students find that some form of heat or energy is involved in change. Investigations in the final Physical Science unit focus on energy relationships. Students invent heat-measuring devices and derive the calorie as a standard unit of heat measurement. All these physical science concepts are applied in study of the environment.

Concurrently, in the Ecology strand, students investigate plants, animals, and the physical environment, in the laboratory and in an outdoor class study area. In the Plant Growth unit they develop an understanding of experimental design in investigating the effects of scarification on the germination of seeds with hard coats. They then design their own experiments to investigate environmental effects on plant propagation. The units emphasize experimental design and communicating findings orally and in writing.

In the Animal Care unit, students raise an animal from the class study area through one life cycle. They learn about life needs, behaviors,

habitats, and niches, as well as interactions with other organisms. They study the interactions and movements of water through the soil, air, and plants in the Physical Environment unit. They build their own instruments for analyzing soil-water interactions, collecting weather data, collecting and measuring raindrops, and measuring transpiration. In the final activity of the unit, they trace the water cycle from their investigations.

The Field Ecology unit is designed to unite all of the Ecology strand into a whole. It focuses on the interactions and interdependence among plants, animals, and the physical environment in the class study area. Students build field-mapping instruments and make a detailed scale map of their study area. They also conduct quadrat studies of environmental change over time and learn how to estimate population sizes by using sampling techniques. In the last investigation, they conduct their own research of an ecological problem within the study area.

Through the Relational Study strand, students focus on the interrelationships of their studies in Physical Science and Ecology. For instance, their knowledge of buoyancy is applied to explaining floating and sinking objects in the environment, the floating of clouds, and the working of their soil analysis apparatus. Similarly, their knowledge of change of state and specific heats enables students to explain weather phenomena, ocean and air currents, air pressure, and the movement of water in the hydrologic cycle.

In addition, the Relational Study strand contains two units that call for students to draw on what they have learned in both Physical Science and Ecology during the year and apply their knowledge and skills to the study of a community environmental issue—either air pollution or water resource management.

One of the major objectives of *FAST* is to develop skills in measurement and in laboratory practice. Students learn to manipulate standard laboratory equipment such as metersticks, balances, glassware, graduated cylinders, thermometers, overflow cups, and heating devices. They learn and practice safe laboratory procedures.

FAST also emphasizes research skills such as planning, designing, and executing valid experiments, collecting and organizing data, constructing and using graphs, and communicating results. *FAST* investigations develop thinking and problem-solving skills as well as manipulative skills.

In addition to science skills, *FAST* fosters and enhances interpersonal skills. Most work is done in small collaborative groups where students share leadership as they share data, ideas, and inventions. The ability to get along with others, cooperate, and get a job done is cultivated through example and practice. All these skills are considered foundational for general education and scientific endeavor.

Schedule and Sequence of Units

The Ecology and Physical Science strands of *FAST* are presented concurrently by alternating short sequences of investigations from each strand. Ecology units overlap, one unit often beginning before previous units are completed. This is especially true of investigations that depend on the weather. Such investigations should be started even though previous units may not be finished. See the schedule on page 12.

The concurrent and alternating presentation of the Physical Science and Ecology strands provides frequent changes of pace. Alternating between strands gives students time to reflect on observations, to see the application of observations in a different setting, and to avoid getting bogged down in the details of investigations. Alternating allows time for long-term data collection required by many Ecology investigations.

FAST 1 as a Two-Year Program

FAST 1, The Local Environment, has been adapted by many school systems as a two-year science program. Because the course is designed to contain more investigations than can be completed in one year, it lends itself well to such adaptation. The extended use of *FAST 1* over two grade levels ensures that students more completely grasp the foundational skills and concepts that are the essence of *FAST*.

A suggested schedule for using *FAST 1* as a two-year program appears on pages 12 and 13. Investigations in Physical Science are again approached sequentially, beginning with Investigation 1, Liquids and Vials. In Ecology, the study of animals is suggested each year. In the first year, students should care for small animals such as mice, rabbits, quail, guinea pigs, and gerbils. In the second year they should focus on insects and similar organisms suggested in the Animal Care unit. This plan gives them experience in handling and caring for small mammals and birds before they do more sophisticated animal investigations. To maintain the structure and philosophy of *FAST*, one Relational Study unit should be done each year.

Suggested Schedule for Using *FAST 1* as a One-Year Science Program

MONTH	PHYSICAL SCIENCE	ECOLOGY				RELATIONAL STUDY
		Unit 1 Plant Growth	Unit 2 Physical Environment	Unit 3 Animal Care	Unit 4 Field Ecology	
Sept.	Unit 1 Introduction to the Properties of Matter	Seed Germination				
Oct.		Plant Propagation	Soil and Water		Field Survey	
Nov.						
Dec.	Unit 2 Changes of State in Matter		Water in the Air			
Jan.			Weather Station		Field Sampling	
Feb.				Animal Care		
Mar.	Unit 3 Temperature and Heat		Rain			
Apr.					Field Ecology	Air Pollution or Water Resource Management
May			Water out of Plants			
June						

Suggested Schedule for Using *FAST 1* as a Two-Year Science Program: Year 1

MONTH	PHYSICAL SCIENCE	ECOLOGY				RELATIONAL STUDY
		Unit 1 Plant Growth	Unit 2 Physical Environment	Unit 3 Animal Care	Unit 4 Field Ecology	
Sept.	Unit 1 Investigations 1 to 12	Seed Germination			Initial Field Survey	
Oct.			Soil and Water			
Nov.						
Dec.			Water in the Air			
Jan.	Investigations 13 & 14					
Feb.			Weather Station	Animal Care	Repeat Quadrats	
Mar.	Investigations 15 to 17	Plant Propagation				Water Resource Management
Apr.			Rain			
May			Water out of Plants		Repeat Quadrats	
June						

Suggested Schedule for Using *FAST 1* as a Two-Year Science Program: Year 2

<table>
<tr><th rowspan="2">MONTH</th><th rowspan="2">PHYSICAL SCIENCE</th><th colspan="4">ECOLOGY</th><th rowspan="2">RELATIONAL STUDY</th></tr>
<tr><th>Unit 1
Plant Growth</th><th>Unit 2
Physical Environment</th><th>Unit 3
Animal Care</th><th>Unit 4
Field Ecology</th></tr>
<tr><td>Sept.</td><td rowspan="4">Unit 2
Changes of State in Matter</td><td></td><td></td><td></td><td rowspan="2">Field Survey</td><td></td></tr>
<tr><td>Oct.</td><td></td><td></td><td rowspan="4">Animal Care</td><td></td></tr>
<tr><td>Nov.</td><td></td><td></td><td rowspan="4">Field Sampling (add soil tests)</td><td></td></tr>
<tr><td>Dec.</td><td></td><td></td><td></td></tr>
<tr><td>Jan.</td><td></td><td></td><td></td><td></td><td>Weather Stations</td></tr>
<tr><td>Feb.</td><td rowspan="4">Unit 3
Temperature and Heat</td><td></td><td></td><td></td><td rowspan="2">Air Pollution Measurement</td></tr>
<tr><td>Mar.</td><td></td><td></td><td></td><td rowspan="2">Field Resurvey</td></tr>
<tr><td>Apr.</td><td></td><td></td><td></td><td rowspan="3">Field Ecology</td><td rowspan="3">Air Pollution</td></tr>
<tr><td>May</td><td></td><td></td><td></td><td></td></tr>
<tr><td>June</td><td></td><td></td><td></td><td></td><td></td></tr>
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THE FLOW OF MATTER AND ENERGY THROUGH THE BIOSPHERE (FAST 2)

The unifying theme of *FAST 2* is the transfer of matter and energy through ecosystems. Student investigations establish that the processes of photosynthesis, respiration, and decomposition are carried on by living organisms; that there is conservation and cycling of matter in the biosphere; that solar radiation entering the biosphere eventually leaves the system as heat. The role of humans as controllers of forced ecosystems is also studied. From these investigations emerges the realization that all organisms are part of a complex interdependent biosphere.

FAST 2 gives students a realistic perspective on human beings as environmental manipulators in a world of finite matter and energy. Students investigate the pressing problems of overpopulation and worldwide shortages of food and fuel. *FAST 2* develops the theme that humans can and must plan for the world of the future. Since humans are decision makers and agents of change, they must consider the technological, social, economic, and ecological implications of their actions. *FAST 2* is based on the assumption that students must understand the processes and interactions of the ecosystems of the planet, make a commitment, and take responsibility for environmental quality as they become citizens of the world.

Physical Science investigations support ecological studies. The Physical Science strand begins with an inquiry into the Newtonian physics of light. Students investigate the nature of light (including measurement of the solar constant), absorption, transmission, reflection, refraction, diffusion, color, and the spectrum. They define energy as anything that can be converted into and measured as heat and explore the relationship between light and heat. (This is an older definition. *FAST 3* develops the more modern definition that energy is anything that can produce work.)

Students then search for evidence of the existence of atoms by analyzing and synthesizing various compounds. These investigations provide good support at the molecular level for the assumptions of conservation of matter made in the Ecology studies. In a brief review of the history of chemistry they search for further evidence to support an atomic theory. Finally, they investigate the kinetic molecular theory of matter and apply it to explaining various molecular phenomena.

The Ecology strand focuses on matter and energy transfer in ecosystems. Students first investigate the interaction of plants and light. Through a series of laboratory and field studies, they identify the process of photosynthesis and generate a model of a producer. Then they investigate respiration as a process of matter and energy conversion in both plants and animals. Out of this study, they develop a model of a consumer. They study the special group of consumers called decomposers by making compost and observing the process of decomposition. They compare the processes of

photosynthesis, respiration, and decomposition. They develop the concepts of interdependence of all living organisms, the cycling of matter in ecosystems, and the flow of energy through ecosystems.

In the Relational Study strand, students apply their knowledge of the transfer of matter and energy in ecosystems to a real system that they design, either field garden plots or microecosystems in gallon jars. By manipulating components of the system, they create a forced ecosystem that maximizes the production of one or more products.

In the unit on world food production, students develop a realistic perspective on humans as capable of manipulating the pathways of matter and energy use in ecosystems to meet their desires. They analyze one or more of the energy problems facing the world, such as the shortage of food or fossil fuel. Students engage in decision-making situations in an attempt to confront these global problems and seek solutions to them.

FAST 2 students build on the skills learned in *FAST 1*. *FAST 2* assumes that students know how to handle standard laboratory equipment and provides additional practice.

FAST 2 emphasizes research skills. Students design many more of their own experiments, paying careful attention to controls, replication, and other features of valid experimental design. They are increasingly responsible for identifying problems, formulating hypotheses, designing tests, conducting experiments, preparing data tables, collecting data, and communicating the results of their work. Increasingly they rely on reading as a method of gathering needed information. Further opportunity for developing interpersonal skills is also an integral part of the skills development of *FAST 2*.

New research tools are added to the students' expanding repertoire. In *FAST 2* they learn to do chromatography to separate and identify substances; to generate and identify various gases; to analyze compounds by heating, blowpiping, electrolysis, and acid analysis; to test for the presence of carbohydrates, fats, and proteins; and to measure energy as heat. They learn valuable horticultural skills in preparing their garden plots.

Systems analysis is introduced in *FAST 2* as a technique to simplify complex problems and to account for components of a system. Students use systems analysis extensively throughout Physical Science and Ecology for cataloging what they know about a system and for visually summarizing relationships.

Schedule and Sequence of Units

FAST 2 Physical Science and Ecology strands begin where *FAST 1* ended and build on concepts and skills developed in *FAST 1*. *FAST 1* Physical Science ends with investigations of the relationship between temperature and heat, with emphasis on the measurement of heat. In *FAST 1* the calorie is introduced. If these investigations were not completed by

students in *FAST 1*, they should be done *before* students begin *FAST 2* Physical Science. See the *FAST 2* Teacher's Guide for specific suggestions.

As in *FAST 1*, both Physical Science and Ecology are taught by alternating sequences of investigations in each strand. The Relational Study is much more evident in *FAST 2*. Concepts developed in one strand are used to investigate new problems in the other strand.

Suggested Schedule for *FAST 2*

<table>
<tr><th>MONTH</th><th>PHYSICAL SCIENCE</th><th>ECOLOGY</th><th>RELATIONAL STUDY</th></tr>
<tr><td>Sept.</td><td rowspan="2">Unit 21
Light & Heat</td><td rowspan="2">Unit 21
Primary Production</td><td rowspan="7"></td></tr>
<tr><td>Oct.</td></tr>
<tr><td>Nov.</td><td rowspan="2"></td></tr>
<tr><td>Dec.</td><td rowspan="3">Unit 22
Evidence for an Atomic Theory</td><td rowspan="3">Unit 22
Respiration</td></tr>
<tr><td>Jan.</td></tr>
<tr><td>Feb.</td></tr>
<tr><td>Mar.</td><td rowspan="2"></td><td rowspan="3">Unit 23
Decomposition and Cycling of Matter</td></tr>
<tr><td>Apr.</td><td rowspan="2">Unit 23
A Model of Matter</td><td rowspan="2">Unit 21
Productivity in Ecosystems</td></tr>
<tr><td>May</td></tr>
<tr><td>June</td><td colspan="2"></td><td>Unit 22
World Food Production</td></tr>
</table>

CHANGE OVER TIME (FAST 3)

The unifying theme of *FAST 3* is change over time. The course relates the concepts of physics, chemistry, geology, and the life sciences through the study of changes in the earth, living things, the solar system, and the universe. By studying change in different parts of the environment, students learn about events that are happening now or have happened in the past, then use their knowledge to predict events in the future. The concept of time is extended back 15 billion years to the hypothetical formation of the solar system, then forward to the era of students' own adulthood and beyond.

Students begin their study of physical science and the earth sciences by measuring force, gravity, work, and energy in laboratory investigations. These concepts are basic to interpreting the interactions of matter and energy, which they investigate in studies of mountain formation, weathering and erosion, theories of the origin and structure of the universe, the evolution of stars, the formation of Earth, and plate tectonics.

In their study of ecology and the life sciences, students advance hypotheses that suggest conditions necessary for supporting life and develop an operational definition of life itself. They identify the structure of organic molecules characteristic of life, explore alternative theories of molecular evolution, and investigate the probabilities of changes in life forms over time.

They then shift focus, examining changes in ecosystems and the effects of living organisms on their environments. By investigating how living things interact with their environments and with each other, they gain insight into how organisms and ecosystems change over time.

In the Relational Study strand, students explore the interactions of science, technology, and society. They consider the history of humans as they have gained control over increasing amounts of energy, first as hunters, then as agriculturists, and finally as industrialists. The course concludes in a series of simulations in which students take the roles of decision makers coping with problems of resource depletion, overpopulation, energy consumption, and other forms of environmental stress.

FAST 3 students continue to use basic lab skills developed in *FAST 1* and *FAST 2*, getting further practice in applying them as they develop their interpersonal skills.

In addition to gathering data through experimentation, students increasingly rely on the work of practicing scientists to build models of how Earth and its environments have changed over time. Communication of ideas becomes increasingly important. Prediction of future events based on knowledge of past and current events is further cultivated. Students come to see scientific "fact" as tentative and changing in the light of new evidence or new interpretations of old data.

Schedule and Sequence of Units

FAST 3 consists of seven units. Though they are numbered consecutively, the units and their sections can be introduced in a variety of sequences. Several of the units are designed to overlap in time so that a variety of activities can be used simultaneously to engage students and capitalize on interest and motivation.

Unit 1, Force, Work, and Energy, is designed to introduce the course. It focuses on the energy involved in physical changes in the environment. The concepts developed in this unit are applied in later investigations to help explain changes. The following page shows a suggested sequence of units.

Suggested Schedule for *FAST 3*

MONTH	Unit 1 Force, Work, and Energy	Unit 2 The Changing Earth	Unit 3 The Changing Universe	Unit 4 Life on Earth	Unit 5 Continental Drift	Unit 6 Changing Ecosystems	Unit 7 Humans in the Environment
Sept.	Force, Work, and Energy						
Oct.		Weathering and Erosion					
Nov.		Volcanism and Mountain Building					
Dec.		Time and Geologic Time	General Motion in the Universe				
Jan.			Models of the Universe	Characteristics of Life		Populations	
Feb.				Origins and Changes in Life Forms	Development of a Theory	Limits to Growth	
Mar.					New Evidence	Adaptations	
Apr.						Population Interactions	Energy on Earth Human Use of Energy and Environment
May							Decisions for the Future Simulation Game
June							

INSTRUCTIONAL MATERIALS

A variety of student and teacher materials is available to guide and support *FAST* investigations.

STUDENT MATERIALS

Student book
Student record book
Reference booklets

TEACHER MATERIALS

Teacher's guide
Instructional guide
Evaluation guide
Data management software

Student Book

FAST student books contain background information, problem statements, procedures to guide investigations, and summary questions that focus on generalizations to be drawn from each activity. As students progress through the course, they write their own and the class's observations, data, hypotheses, and conclusions in their notebooks. Their running logs of investigations become their own textbooks. The student book is a guide to the sequencing of investigations. Its Appendix provides information on the metric measurement system and describes instruments and units for measuring linear distance, mass, area, volume, temperature, and time.

Student Record Book

The student record book contains both data tables and space for recording notes and observations of investigations presented in the student book. The record book enables students to maintain a concise log of individual and class activities. It fits in a three-ring binder along with the student's own notes.

Reference Booklets

To support investigations, a classroom library of reference booklets is provided. These booklets describe the use of instruments, suggest experimental designs, outline experimental techniques, and provide supplemental information as needed. The booklets give students practice in using outside references to supplement the information they derive from their own investigations.

The following reference booklets are available for *FAST 1:*

"Air Pollution"
Discussion of means of measuring pollution, assessing its effects, and controlling it in any environment, with an examination of technologies for pollution control and an annotated list of federal laws pertaining to pollution.

"Animal Care"

Instructions for building cages and environments for keeping animals often found on schoolgrounds, with basic information on the food and habitat needs of 35 kinds of animals.

"Field Mapping"

Instructions for making detailed, scaled, and contour-lined maps of a class study area and for making and using mapping tools such as a stringed meterstick, a sighter, a range pole, and a meter level.

"Plant Propagation"

Propagating and growing plants from bulbs, cuttings, seeds, seedlings, and underground parts, with techniques for grafting, air layering, and using hydroponic solutions; investigations of each method; discussion of dormancy, planting containers and media, and watering.

"Sampling Methods"

Techniques for determining population size, density, and frequency by random sampling and by using quadrats, transects, and other methods.

"Weather Instruments"

Instructions for building a weather station, for making weather instruments including a rain gauge, a hygrometer, a wind vane, and an anemometer, and for setting up instruments to measure air quality.

These reference booklets are available for *FAST 2:*

"Chromatography"

Procedures for separating pigments by paper chromatography and thin-layer chromatography with inexpensive materials—filter paper and silica gel; instructions for preparing leaf pigment extracts.

"Components of Biomass"

Instructions for simple tests to identify such components of plant and animal biomass as starch, sugar, protein, amino acids, fats, carbon, and water.

"Composting"

Procedures for making aerobic and anaerobic compost, with methods of investigating decomposition processes.

"Elements and Compounds"

Instructions for identifying elements and compounds by their physical and chemical properties, with descriptions of 10 elements and 12 compounds.

"Field Productivity"

A gardening guide with instructions for using PERT diagrams and decision-theory techniques to plan a garden and with advice about soil testing, supplying water and nutrients, and coping with pests to maintain a healthy crop.

"Gases"

The properties of the gases studied in *FAST 2*, with methods for generating, identifying, and removing them—all useful in investigating the gases produced in photosynthesis, respiration, and decomposition.

These reference booklets are available for *FAST 3:*

"Components of Biomass"

Instructions for simple tests to identify such components of plant and animal biomass as starch, sugar, protein, amino acids, fats, carbon, and water.

"Organism Maintenance"

Care of such laboratory animals as brine shrimp, daphnia, mole crabs, mealworms, sow bugs, and yeasts, with suggested investigations.

Teacher's Guide

The logic connecting investigations and strands is explained in the teacher's guide. The guide, which is keyed to the investigations in the student book, contains teaching suggestions, advice on classroom procedures, and detailed discussion of the conceptual and practical progression of the student investigations. It also includes lists of equipment and chemicals, suggested schedules, and other information for using the program.

Instructional Guide

The instructional guide explains the philosophy, objectives, and design of the *FAST* program. It describes *FAST* components and suggests schedules, sequences, and strategies for organizing and managing the class.

Evaluation Guide

The evaluation guide describes the kinds of student evaluations built into the *FAST* program and tells how to use them to help students achieve their potential. It includes tests for assessing laboratory skills and understanding of concepts. The evaluations are also a means of involving students in self-evaluation. The guide contains a series of class progress records and an inventory of skills and concepts for use as individual progress records.

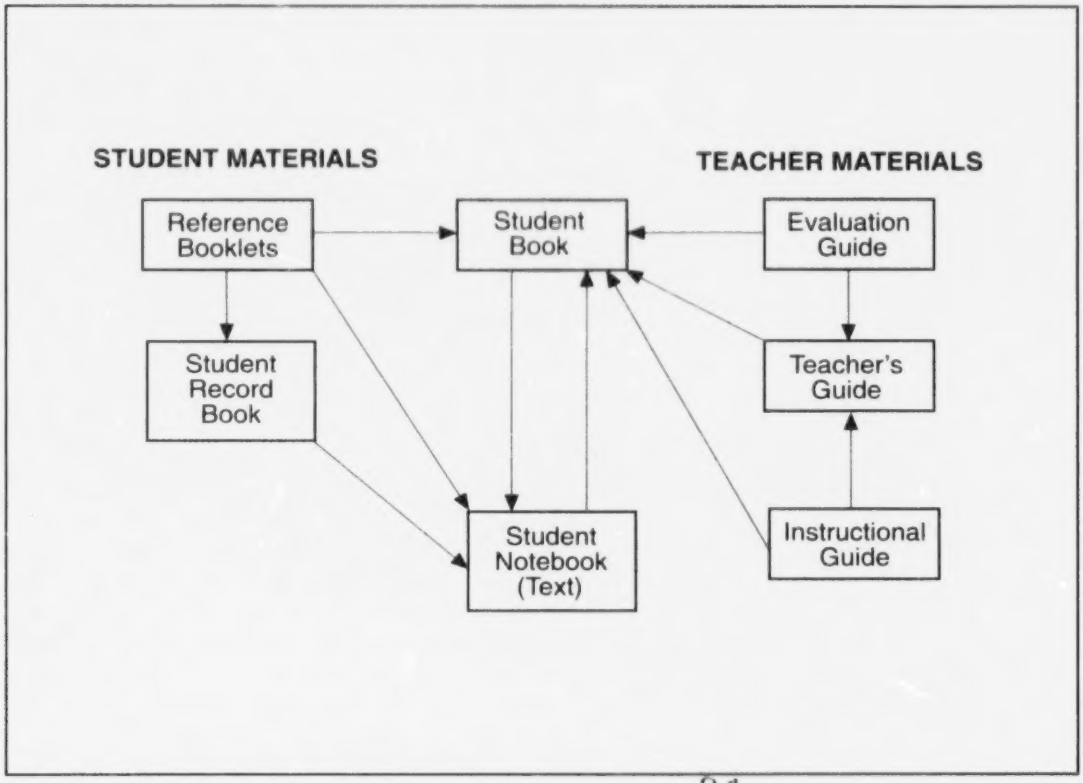
These progress records are designed to help students and teachers know which concepts and skills have been mastered and which ones should be further developed to meet the expectations of the program. Software for Macintosh or Apple IIe computers is available to complement the evaluation guide. This software eases monitoring of student performance on *FAST* evaluations and provides printouts of class progress records and student progress records.

Data Management Software

Software specific to investigations in *FAST 1* is available for Macintosh and Apple IIe computers. The software enables students or teachers to enter experimental data; the computer displays data tables and a graphic analysis of the class data. Printout options include data tables, graphs of plotted data, and graphs of plotted data with line of best fit.

SUPPORT DESIGN AND *FAST* MATERIALS

The figure below shows how the *FAST* instructional materials support one another. The student book and student notebook are the central focus of students and teachers because these materials guide progress through the course.



INSTRUCTIONAL MATERIALS FORMAT

With occasional exceptions, this format is used for investigations in the student book.

Format of Student Book

INVESTIGATION NUMBER AND TITLE

Background

Introduces the investigation and reviews earlier related investigations.

Problem or Activity

States a question to be answered or an activity to be done.

Materials

Lists the equipment and supplies needed for an investigation.

Procedure

Gives instructions for doing an investigation.

Summary

Asks questions to guide analysis and interpretation of results of the investigation.

Challenge

Suggests further investigations.
Sometimes leads into the next investigation.

Format of Teacher's Guide

Each strand in *FAST* is organized by units. Most units have two or more sections, each a sequence of investigations to be done by students.

UNIT

UNIT NUMBER AND TITLE

RATIONALE

Describes reasons for including the unit in the course.
Relates unit to other units.
States objectives of the unit.

OVERVIEW

Describes content and activities of the unit.
Relates sections of the unit to one another.

STRATEGY

Suggests ways to introduce and teach the unit.
Specifies required weather considerations and other information.

SECTION

SECTION TITLE

RATIONALE

Details goals and objectives of the section.
Relates section to other sections.

OVERVIEW

Describes content and activities in the section.

STRATEGY

Suggests ways to introduce and teach the section.
Details some useful techniques.
Specifies weather requirements, if any.

SUGGESTED SCHEDULE

Recommends sequence and time allotments for each investigation.

Investigations

Each investigation, whatever its length, begins with a digest designed as a one-page lesson plan. After the digest comes a description of the rationale and objectives of the investigation, then an overview of the student activities with a list of needed materials. Notes for the teacher follow, organized under the same headings as in the digest: review, introduction of new work, student activities, summary, and challenge. These notes provide detailed suggestions for organizing and teaching each investigation.

DIGEST

REVIEW

General statements reviewing pertinent ideas developed previously

INTRODUCTION OF NEW WORK

Suggested approaches to the new topic

VOCABULARY

A list of new words introduced in the investigation.

Single boxes indicate teacher responsibilities.

STUDENT ACTIVITY

Problem: Statement of the problem or activity (from the student book)

Flow diagrams of procedures and apparatus

Procedures for doing the investigation

SUMMARY

Summary questions about data analysis and generalizations deriving from the investigation

CHALLENGE

Challenge questions (from the student book)

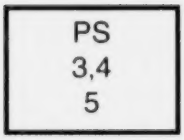
Double boxes indicate student responsibilities.

Graphics Used in the Teacher's Guide

Graphics in the left margin of the teacher's guide identify special information.

The projector logo indicates that a transparency master or optional student page is provided in the packet of Visual Aid Masters accompanying the guide. A transparency master may be a class data sheet or a diagram of instructions.

Optional student pages usually contain too much information to make good transparencies. They may be duplicated for distribution to students.



The square identifies Relational Study connections between strands. The symbol shown here, for example, if it appears in the Ecology strand, indicates that information relating to the topic being pursued is also covered in Physical Science investigations 3, 4, and 5.

The computer logo identifies investigations for which the *FAST* data management software offers a way to analyze and display data.

CLASSROOM ORGANIZATION AND MANAGEMENT

A research team model is used for organizing classes in *FAST*. Instead of disseminating information, the teacher directs the learning process by defining tasks, asking questions, giving suggestions for further investigations, and maintaining an atmosphere of collaborative inquiry.

THE *FAST* TEACHER

1. is the research director-facilitator who coordinates activities, sets tasks, encourages, prods, and keeps inquiry open.
2. focuses students' attention on laboratory and field techniques, experimental design, hypothesis formation, generalization, and practical implications of research.
3. provides materials and directs an efficient, safe classroom/laboratory facility.
4. arranges for access to the laboratory, field, and other sources of information and provides adequate opportunity to complete assigned work.
5. provides incentives and equipment for students to pursue open-ended experimentation.
6. is alert to the intellectual difficulties of students and arranges task assignments, grouping, and presentation to foster development of each student's potential.
7. engages students in self-evaluation.
8. encourages mutual sharing of ideas and labor.

THE *FAST* STUDENT

1. is the researcher working to explain the raw data of experimentation and the implications of findings.
2. observes, formulates hypotheses, designs experiments, and seeks the practical significance of research.
3. maintains a safe and functional experimental environment.
4. uses research as a primary source of concept development and knows that research may be done in field, laboratory, or published sources.
5. explores a given idea as extensively as time allows.
6. accepts challenges and works to extend personal capacity.
7. seeks to evaluate personal achievement.
8. develops the attitudes of a participant in a scientific community.

SUGGESTIONS FOR USING THE PROGRAM

Some general suggestions for teaching *FAST* are stressed in the teacher's guide and during teacher training institutes. They are important enough to bear emphasizing.

1. The roles of the teacher as a facilitator and students as researchers in *FAST* depart from the traditional roles of teachers as active knowledge conveyors and students as passive receptors. Both teacher and students need patience as they develop in these new roles.

2. For the *FAST* program to achieve its fullest potential, teachers must be constantly aware of the need to help students

   a. organize.
   b. summarize.
   c. make connections between investigations.
   d. keep sight of short- and long-range objectives.

   Suggestions for organizing each investigation are in the teacher's guide. Regular review of these suggestions will be helpful, especially during the first year of teaching *FAST*. The summary questions at the end of each investigation are designed to help accomplish the tasks above. They should be treated as an integral part of every investigation and used as a springboard for discussion.

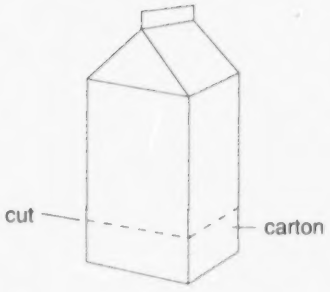
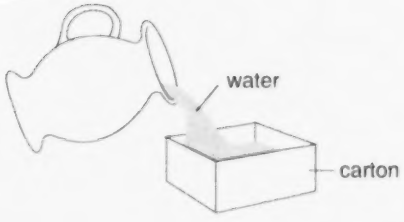
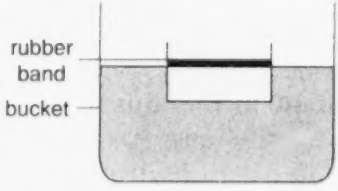
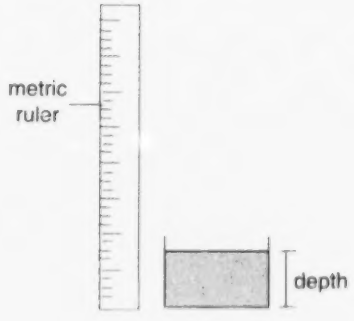
3. To be effective, a "hands-on" science program requires careful preparation and organization. The burden of preparation can be lightened through the cooperation of a self-directed class. Laboratory routines should be established from the very first day so that all students know their personal and shared responsibilities in *FAST*.

   Teachers should help students to assume as much responsibility as possible for laboratory maintenance, setup, and organization. Student lab assistants or a *FAST* club often proves helpful.

4. Peer teaching develops naturally in the *FAST* classroom and should be encouraged. Through teaching, students gain a deeper understanding of skills and concepts. Having learned something new, students can often communicate just-mastered skills and concepts better than teachers can.

5. *FAST* materials are meant to be dynamic and adaptive. Teachers should feel free to use these materials within the context of their own experiences and professional judgment and to adapt, extend, and innovate in the same ways they would with any other instructional program.

6. Using flow diagrams is a proven technique for quickly checking on students' readiness to perform laboratory investigations. A *flow diagram* is a pictorial representation of written directions or procedures. A sample is shown below.

Directions	Flow Diagram
1. Cut off the top of a carton.	
2. Fill the carton about half-full with water.	
3. Put the carton into a bucket of water. Mark the depth of sinking with a rubber band.	
4. Measure the depth of sinking.	

39

Requiring students to sketch flow diagrams of their laboratory procedures before beginning work ensures that they have read the directions. The presence of the flow diagrams in the students' binders is also an aid to the teacher who, with a rapid glance down the column of sketches, can determine if students have understood the directions. Sketching flow diagrams results in clearer understanding of directions than providing students with commercially illustrated directions does. For details of complex pieces of apparatus, students should refer to diagrams in the student book.

FAST 1 students are introduced to flow diagram techniques and given increasing responsibility for their production in each succeeding unit. By the time students are in *FAST 2*, they should be able to read a list of laboratory directions and sketch appropriate flow diagrams with no assistance.

7. Relationships between parts of the program must be regularly raised to consciousness by review. Unless the teacher causes students to periodically look for connections between investigations and concepts within a strand and between strands, students may characterize science as a collection of unrelated parts. Establishing continuity and connection is one of the major purposes of the Relational Study.

   The following kinds of connections should be drawn out in review:

   a. The connection between subcomponents of evolving concepts. For example, in developing understanding of buoyancy, the relationship between mass and volume of an object and the density of the fluid in which it is placed must be carefully laid out.

   b. The use of concepts from one area of science for understanding phenomena in another area of science (the instrumental use of concepts). For example, buoyancy helps explain the movement of parcels of air in the atmosphere.

   c. The use of knowledge developed in science to help guide social decisions.

      In showing relationships, it is important to have students contrast the use of techniques and the kinds of data derived in different areas of science. For example, graphs of biological data give evidence of individual differences among organisms, but graphs of physical systems are far less variable.

      The digests in the teacher's guide are helpful tools for such review. After students have completed a topic, you can post digests on the bulletin board as visual reminders of the development of concepts.

THE STUDENT NOTEBOOK

The students' notebooks and record books constitute their texts. It is extremely important that students begin on the first day of class to keep organized notes on observations, hypotheses, summary questions, and vocabulary. Sixth-graders especially will need direction, encouragement, and help in organizing and keeping their texts up-to-date.

The following are suggestions for developing record-keeping skills:

1. Data should be entered in the tables in the student record book and filed in a three-ring binder. Additional pages will be needed for class notes and answers to summary questions. Added to the notebook, these build a log of individual and class investigations.

2. Some teachers have found that keeping student notebooks in class during the week reduces confusion and makes work more available for checking. Notebooks can be kept in cardboard boxes, in stackable dishpans, on a standard bookshelf or a rolling cart, or other container.

3. Help students develop regular habits and standard procedures for notekeeping.

    a. Always state the problem. Get students in the habit of writing the objectives of the problem or activity before they do anything else. Put the objective on the board or on a chart as a constant reminder for students.

    b. Be sure each student understands data tables. If record books are not used, tables should be prepared before beginning laboratory work. Students should understand that they may need to make additional notes of unusual observations or new hypotheses as they investigate.

    c. During the summary or other times of discussion, have a "recorder" put important points on the board so that everyone can see and record them.

    d. Be sure students keep a vocabulary list and add to it as new words and concepts are introduced. A class vocabulary list posted for reference is also helpful. New words are listed in the digest of each investigation in the teacher's guide.

4. Encourage students to review their notes to make corrections and additions. Make it amply clear that record keeping is a scientific skill like reading a balance. Notekeeping should not be emphasized to the point of frustration, however.

5. Check notebooks often. A checklist to put in student notebooks at the beginning of the year will provide consistent guidelines for completing work. A suggested form follows.

Student Notebook Checksheet

	Date Checked						
1. Investigations are in order.							
2. Investigations are complete.							
3. Graphs and data tables are labeled.							
4. Graphs and data sheets are readable.							
5. Notes are complete for • problem statements.							
• observations.							
• class discussion.							
• summary questions.							
• anomalies.							
• vocabulary.							
6. Errors have been corrected.							
7. Conclusions and hypotheses have been revised to reflect class discussion.							

PLANNING FOR EFFECTIVE GROUP INTERACTION

In the *FAST* laboratory and classroom, the teacher is continually interacting with one or more groups of students. A group may be the entire class or some segment of the class. Group sizes vary according to the objectives of the learning situation. Discussion involving the entire class may be appropriate for some lessons but not for others.

A single group is usually easier for a teacher to manage than several smaller groups, particularly at the start of the year. Here the students usually focus on the teacher and on one topic. But large groups tend to limit discussion because it is difficult for everyone to participate.

When smaller groupings are used, the teacher is not the focal point; the topic or problem being discussed is. Then the teacher must adjust to having different activities going on at one time. Smaller groupings require the teacher to plan lessons carefully and to be ready with questions that generate student engagement and clarify the objectives and tasks of each group. Furthermore, the teacher must know what is happening in each group.

The strength of the small group is that it gives everyone the chance to join the discussion and to contribute ideas. Smaller groups also let individuals assume responsibility for their own learning, participate in decision making, and practice interpersonal communication.

The following pages describe some ways of grouping students for effective group interaction.[1]

Arranging for Groups

Arranging for effective group interaction requires special preparation and planning. Attention must be paid to 1) the general environment in which the groups will operate, 2) the seating and working space, 3) the size of the group or groups to undertake the task at hand, 4) the selection of group members, and 5) the mechanics for sharing group information with the remainder of the class.

The Environment

It is most important to provide an environment conducive to good interaction. Circulate among the groups, try to identify needs, and offer help if you must. But at the same time, relax and allow the groups time to interact before expecting them to act. Below are some ideas for enhancing the comfort and emotional climate of groups.

1. Create an environment that is attractive and pleasant to work in. A cheerful environment puts members at ease and fosters co-operation.

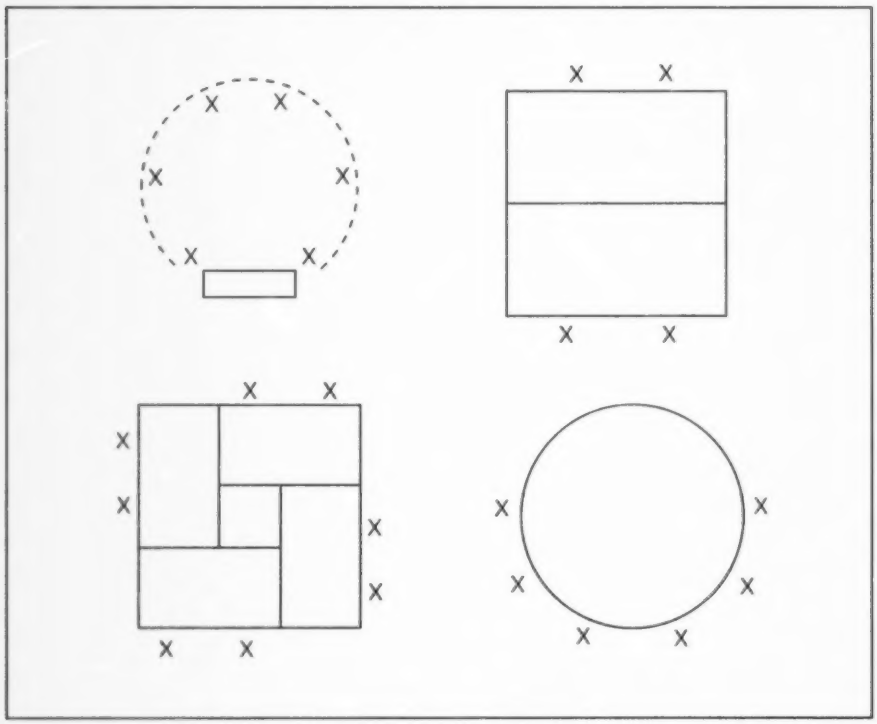
[1]Some of these materials have been adapted from the Investigating Your Environment series developed by the U.S. Forest Service.

2. Be sure the room is properly ventilated and lighted. A stuffy or poorly lighted room causes drowsiness and uneasiness, reflected in less-effective interaction.

Seating

The arrangement of people in a group is important. Circular arrangements have the advantage of allowing each person to see every other person. If possible, provide table space for writing notes and recording discussions.

The arrangement does not only suggest the kind or level of participation; it may even dictate it. For example, in the typical arrangement students face only the teacher, thereby providing good exchange only between the teacher and students. Alternative arrangements encourage more student participation. The diagram below shows some alternative arrangements.



Group Size

The size of a group is determined by the type of task to be done. For some activities or discussions, large groups are appropriate; for others, small groups are better. The teacher must decide when to break a large group into smaller ones or combine smaller groups into a large one. The following examples show how the task or activity may suggest the optimal size for groups.

1. **Conveying information.** When the teacher gives directions, presents new information, or summarizes class activities, groups of 25 to 30 students may be most appropriate. This traditional mode of classroom instruction is illustrated below. In such groups, individual participation is limited.

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2. **Open-ended discussion.** Groups of 10 to 12 people seem optimal for open-ended discussions about controversial topics, especially ones calling for opinions. Such groups are large enough to ensure diversity, yet small enough to encourage participation. See the illustration below.

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3. **Problem-solving.** Whenever it is desirable for a group to focus on a particular problem, share ideas, get consensus, and develop problem-solving strategies, a good size is 4 to 6 people. Groups of this size are used extensively in field project work. Such a group is small enough to ensure high involvement without too much divergence from the task at hand. Once the problem has been introduced, the teacher may wish to join a group or simply let students tackle the problem on their own.

47 BEST COPY AVAILABLE

4. **Laboratory problems.** Most of the laboratory problems in *FAST* call for a team of 2 to 4 students. This number allows each student to engage in the investigation and provides enough hands to perform needed tasks. Further, it ensures an intellectual critical mass, so that investigations are not stymied for want of an idea.

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5. **Short discussion.** Pairs are best used when students are to discuss something quickly without distraction or when the highest level of participation is required, as in laboratory work.

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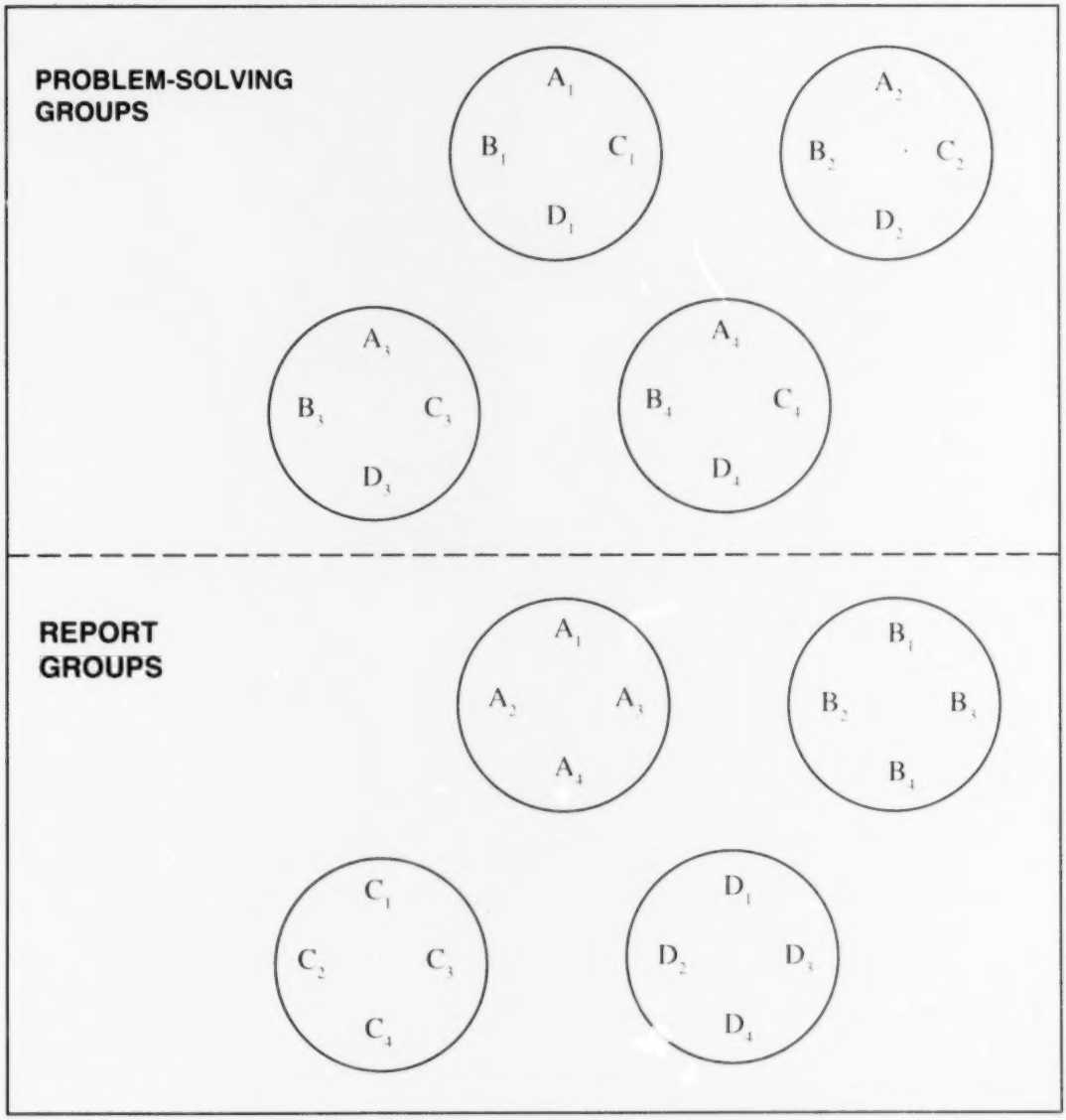
Grouping Students

The mix of students is important to the social-emotional climate of the group. Group members may be teacher-selected or self-selected by preference or interest. If the teacher selects students on a nonrandom basis, care must be taken to balance groups by sex, interest, and ability.

If a topic requires special skills or talents, at least one member of the group should have these skills or talents. For example, poor readers may be grouped with good readers on a task that requires reading so that the group can succeed in the task. Having students work with different groups at varied tasks enhances their opportunities for learning new skills, making new acquaintances, and developing communication skills.

Techniques for Sharing among Groups

When several small groups are working on a similar topic, it is often desirable for them to share information. This can be done by a variety of techniques. For example, one member of each group may share the problems the group encountered. Another arrangement, diagramed below, eliminates the need for large-group reports.



Here members of each problem-solving group are assigned to a report group. Each report group has one member from each problem-solving group.

Establishing the Groups

In the initial stages of developing functioning groups, be sure that students have a clear picture of what is expected of them. Equally important, the group members should know one another. If the group has been formed for discussion or a long-term project, leadership roles need to be specified. Finally, the group must have a purpose for being. This purpose is found in its charge.

Expectations

The role of group activity should be spelled out before students are divided into groups. It is important for students to recognize that a research team approach to inquiry is being used to search out the foundational ideas of science. This will require group cooperation and personal commitment to do one's share of the work assigned.

Initial Leadership

In many group activities the dynamics of the lesson do not require that a leader be named. This is true in lab team activity and paired discussion. However, group projects or discussion in groups of four or more students work better with a recognized group leader to establish responsibility and accountability.

Once the group has been formed, a recorder should be selected by the group or appointed by the teacher. The recorder should be an objective person capable of accurately writing the interactions. The recorder's role is to accept and report or record the contributions of group members. The recorder should record the essence of contributions without modifying or censoring it.

The Charge

The final product of a group can be no better than the charge under which it operates. In the earliest stages of their functioning, groups must have a clear picture of what they are to do. Often this is a statement made by the teacher, sometimes by the program materials, sometimes by the decision of the group. In all cases, the first action on the agenda after organizing is to review the charge for clarity if it is given, or to formulate the charge if it is the responsibility of the group.

Stages of Group Interaction

Every group has to learn to work together. Usually some feelings develop between members during their learning process, especially when the group is first formed. It takes time for members to learn to fit into the group and to contribute to the group. Things often seem "all mixed up," and members may become disturbed and discouraged, even angry at each other. It may help to know that these are natural stages in the development of effective group interaction, that these feelings tend to follow a predictable progression, and that in most cases the group soon becomes productive and efficient.

Described on the next few pages are some of the stages that groups may go through during this process. Though most groups go through these stages, no one stage is essential. Some groups may begin at stage 3, 4, or even 5. Other groups may never get past stage 3 or 4.

1. **Groping stage.** When a group of students is first finding out how to work together, they may not all agree. They do not know or understand one another well enough to *trust* each other. They still have to identify each other's skills, knowledge, and attitudes. They may feel uncomfortable, even frustrated.

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2. **Griping stage.** A group tends to get discouraged when members cannot seem to work together, when there is little progress, or when their attempts are frustrated. They may attack one another verbally, play negative roles, and block group action because they are uncomfortable. Though members have different strengths and interests, they all want to do a good job and to be liked. The desire to do the job well usually holds the group together and allows it to progress to the next stage.

55

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3. **Grasping stage.** With patience and guidance, ideas and suggestions start to fit together. The group begins to agree on questions and feel more comfortable with the realization that it is getting somewhere.

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4. **Grouping stage.** When students get to know each other, they begin to understand and appreciate how other members operate and contribute. The group begins to function well, members begin to assume building and maintenance roles to keep the group operating at a high level, and a surge of enthusiasm spreads through the group. A feeling of "my group" begins to emerge.

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5. **Acting stage.** When the group is in full swing, all members play constructive roles, share leadership, and participate. Ideally, all group members are sharing in making plans and decisions and are learning together. They feel that this is a good group to work with.

58

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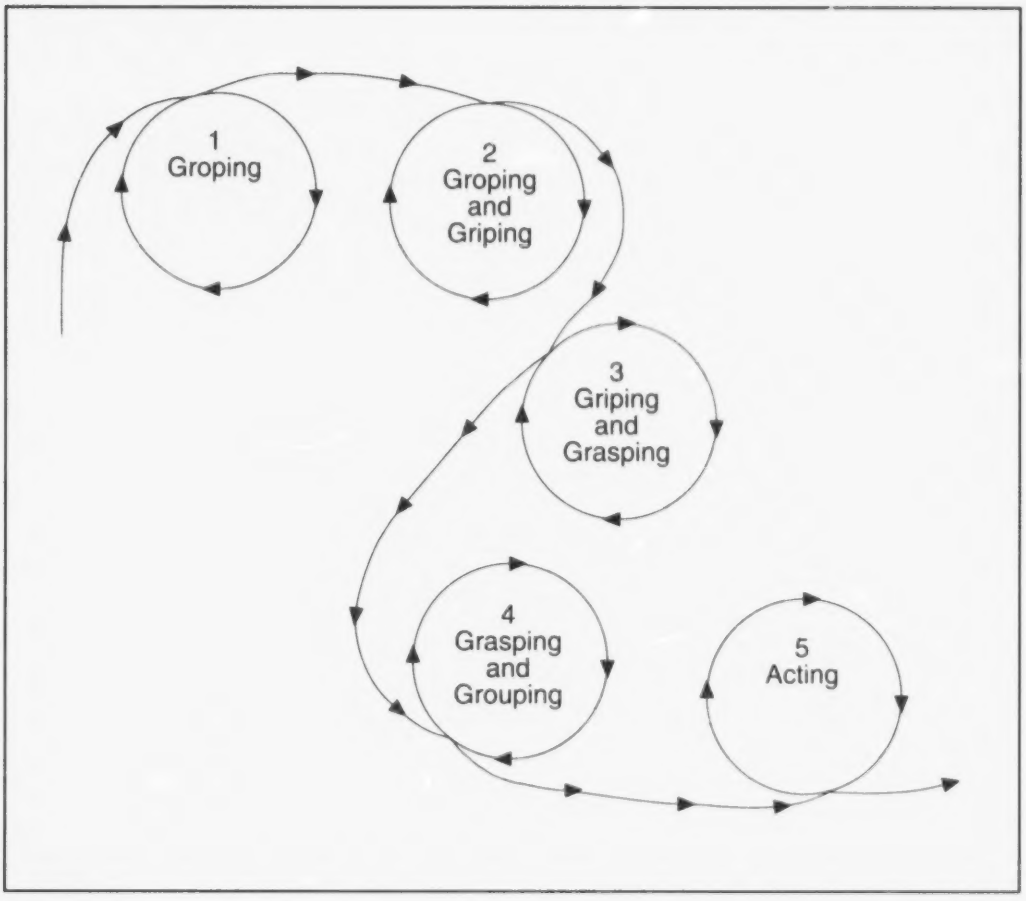
Stages of Group Interaction



These stages characterize how group members *feel*. They are independent of the content being addressed by the group. It is important for the teacher to recognize that negative feelings are natural when a group first tries to work together, and to realize that despite such feelings, groups can move ahead toward more harmonious relations. As members get to know one another better, *a* group gradually becomes *their* group because they have shared plans and work and have tried to practice cooperative, considerate, and friendly ways of behaving.

The teacher's role during group formation is to try to identify the stage the group is in and to facilitate movement to a more productive stage. The teacher tries to see that everyone feels included and accepted and tries to get the group to address the task at hand. This is done by suggesting procedures, focusing and refocusing group attention on the topic, clarifying statements and directions, and summarizing progress. Carefully planned questioning strategies move the process along. Suggestions for improving group action are in the section "Facilitating Group Discussion."

Characteristics of Effective Groups

Although other factors contribute to the effectiveness of groups, communication is the most important, for without it there can be no effective group interaction. Good communication depends on 1) open sharing of ideas, 2) listening attentively, and 3) feedback to ensure clear understanding of what is being said. The following are some of the characteristics that reflect open communication.

1. The effective group knows why it was formed and what it is to do.

2. The effective group openly communicates feelings and attitudes because members recognize that open communication helps the group function.

3. The effective group makes sure that all members express themselves on important decisions; it is not dominated by the ideas of the leader or any one member.

4. The effective group listens attentively to ideas expressed by its members.

5. The effective group recognizes that all members and their ideas are important.

6. The effective group accepts that each member is unique and has personal needs that must be met.

7. The effective group recognizes the different talents and abilities of each member and tries to make use of them.

8. The effective group recognizes that its success is the responsibility of all members, not just the leader.

9. The effective group shares the responsibility for leadership, with each member assuming leadership at one time or another.

Student Group Leadership

The key to sustaining the quality of group activity is the group leader who initiates and preserves good interaction. The successful leader consciously builds and maintains a positive social-emotional climate within the group through behavior, attitudes, and actions. Experience in *FAST* has shown that the skills of effective leadership can be learned not only by teachers but also by students.

The Effective Leader

It has often been assumed that group leaders have special traits. Many studies have attempted to correlate leadership capacity with personal attributes. While some definable personal characteristics have been linked to leaders in certain situations, these studies have not succeeded in devising a formula for selecting leaders. The current view is that leadership is functional or "job-centered." We should ask, "What does an effective leader *do?*" rather than "What kind of person will be a good leader?"

The things a good leader does fall into three categories—personal behavior, communication skills, and organization. Some of the characteristics in each category are listed below.

Personal behavior. The effective leader

- establishes an accepting and trusting environment.
- shows sensitivity to the feelings of the group.
- shows sensitivity to the needs of the group.
- listens attentively.
- recognizes that each member is important and needs recognition.
- recognizes that leadership can be shared and is not to be monopolized.
- refrains from arguing.
- refrains from criticizing or ridiculing members' suggestions.

Communication skills. The effective leader

- makes sure that goals and objectives are clearly defined.
- makes sure that everyone understands not only what is needed but also why it is needed.
- makes good communication within the group a routine part of the job.

Organization. The effective leader

- establishes a physically comfortable environment.
- develops and identifies long-range and short-range objectives.
- breaks big problems into smaller ones.
- shares opportunities and responsibilities.
- plans, acts, follows up, and evaluates.

The Nature of Leadership

Leadership is helping others work toward common goals or purposes. It may be regarded as a series of functions that 1) help individuals to feel at ease in a group (including looking after the physical setting and getting acquainted), 2) build and maintain a group over a period of time, 3) help to set and define objectives, 4) achieve a cooperative esprit de corps allowing a group to work toward attaining set objectives, and 5) get a job or task done.

Group leaders must consciously build and maintain a positive social-emotional climate within which all members of the group can participate meaningfully. The social-emotional climate can advance or impede group operation. People tend to be cautious about exposing their ideas to value judgments of others.

Art and craft. The ability to lead effectively can be learned through conscientious effort, study, and practice. Leadership is both an art and a craft. The skills of the craft are learnable. By understanding and conscientiously practicing some of these principles, anyone can become a better leader. The art of leadership develops through application of leadership skills.

Shared leadership. Ideally, all members of a student group should at some time assume a leadership role. Leading not only contributes to the growth and development of both members and leader; it also pools the skills and abilities of the entire group, promotes a spirit of unity ("my group" feeling), intensifies each member's sense of responsibility for group maintenance, gives members a stake in goals and objectives they help establish, and promotes a feeling of satisfaction as group members share in common achievements.

The Teacher and Shared Leadership

The teacher's responsibilities in arranging situations in which leadership can be shared with students include the following:

1. Clearly defining goals and objectives as identified and agreed upon by the group

2. Establishing an accepting and trusting environment in which group members are free from criticism or ridicule

3. Establishing a setting where group members are socially at ease and physically comfortable

Summary

The ability of a group to achieve its goals depends to a great extent on whether its members can communicate well among themselves and with others outside the group. Group members must feel comfortable both emotionally and physically. After the group has been formed, has begun to feel at ease, and has identified its task, it may begin operating at any one of several stages. Eventually, as interaction becomes more directed and constructive, the group will begin acting on the task at hand, making decisions, recommending actions, and so on.

The group leader is the most important element in facilitating group interaction and discussion. The leader must know and practice behaviors that are accepting, encouraging, and supporting of group members. The leader must also know how to listen and respond to group members and help them direct their efforts toward the task at hand.

These leadership skills are important for students to know. In the *FAST* classroom many kinds of grouping are used. The teacher is not always the leader. Leadership is often shared with students functioning as small-group leaders. The techniques of effective leadership should be shared with students and opportunities provided for each student to practice the role of group leader.

FACILITATING GROUP DISCUSSION

In most classes, discussion is important in the learning process. In inquiry instruction it is essential. Discussion lets students articulate what they know, tell others what they know, and listen to others' points of view. In inquiry classes, where groups collaborate on learning activities, students must discuss their work extensively to accomplish it successfully. Just having students perform investigations does not constitute teaching them science, because they do not discover science concepts and generalizations on their own. The role of teachers in guiding students' discussions of their work is therefore pivotal. Teachers must help students make connections between what they already know and what they are learning—new concepts, skills, or applications.

Discussion holds a prominent place in the *FAST* instructional system. Discussions begin and end each investigation. At first, teachers must generate and stimulate discussion. But as the year progresses, students assume increasing responsibility for discussion as they become aware of its place in inquiry, in developing concepts, and in refining their thinking.

Discussion may be used for many purposes:

- Guiding and directing investigations
- Reviewing concepts and skills already in students' backgrounds
- Introducing and identifying new problems or areas for investigation
- Generating hypotheses
- Planning experimental procedures
- Analyzing and interpreting data
- Assessing and revising hypotheses
- Formulating and analyzing conclusions
- Summarizing activities or experiments

Discussion in Inquiry Science

Inquiry science presents many opportunities for creative expression that teachers and students should notice and seize. Investigations offer unique occasions for students to invent things, make decisions, and try out their

ideas. Discussion opens these inventions, decisions, and ideas to the scrutiny of others. Teachers must hold high expectations of students' creative capacities and communicate them to students. Research shows that high expectations stimulate higher achievement by all students, especially low achievers.

Development of thinking skills and understanding of concepts requires discussion. The teacher's role is critical in moving students from what they already know to richer and deeper understanding of the world around them. In inquiry classes they do this by asking appropriate questions.

Discussion and Inquiry

Taba has described three levels of thinking: recalling, processing, and applying. These levels can be elicited through questioning strategies. Developing higher-level thinking skills in processing and applying information is essential to students' growth as inquirers. Studies of questions asked by teachers show that 70 to 80 percent require only recall. We know from research that questions calling on higher-level thinking skills bring higher-level responses from students. But a mix of questions requiring thinking at all levels seems to yield the greatest growth.

Discussion is central in developing inquiry skills such as observing, inferring, verifying, and hypothesizing. Discussion is especially important after sessions in the field or laboratory. It has been suggested that the apparent failure of some inquiry programs in science may be attributed to the lack of such discussion. Typically, teachers tell students what they should have observed or inferred.

Cognitive Conflict in Inquiry

A special technique in developing inquiry skills is creation of cognitive conflict. The moment of disagreement or conflict is to be cherished, for it motivates students to seek resolution and develop their skill in problem solving. Teachers can intentionally build cognitive conflict in several ways:

- Comparing students' explanations
- Feigning surprise at either a faulty explanation or a correct one
- Posing an impossible event implied by a student's position
- Establishing expectancy for an outcome that testing will not support
- Asking for supporting evidence of a rote answer
- Accepting all observations and explanations until two contradictory ones emerge, then building a discussion on the conflict

The Facilitator of Discussion

Although leadership of discussions most often rests with the teacher, students can develop discussion skills and should be helped to do so. Discussion is appropriate to both large- and small-group interactions.

The discussion leader is here called the facilitator. The facilitator proposes, suggests, invites questions, and attends to both the content of the discussion and the feelings of group members. The facilitator tries to promote meaningful interaction, stimulate responses, and help the group generate its own data.

Guidelines for Facilitators

What follows is a series of guidelines for teachers and students to use in leading discussion. Following these guidelines will enhance both the climate for discussion and the content of discussion.

Encourage participation. When someone is reluctant to enter the discussion, an invitation to disagree, recap, summarize, or just jump in may be all that is needed. Such invitations encourage members by letting them know their contributions are needed, helping them feel they are members of the group.

Discussing often means disagreeing with one's peers. Take advantage of disagreement and encourage participation by seeking divergent ideas. Invite everyone to state views and offer evidence to support them. Disagreement is particularly fruitful if everyone shows an accepting attitude toward differences in opinion and if there is no pressure for closure, no voting, no concern about an impasse.

In inquiry science, a point of impasse is to be specially nurtured, for the crucial question, How do we test our ideas? can then be asked. A side benefit accrues as students learn early that in solving social and technological problems there is no easy answer or no one "right" answer or conclusion. They also find there are different ways to process, interpret, and apply data.

Support group members. Make the discussion area a safe place to enter by showing support for all participants in a discussion, especially students who have problems entering into the mainstream interaction:

- The student who suddenly cannot answer when asked for a response
- The shy student who offers irrelevant information on the first attempt
- The unpopular student whose every comment is attacked by someone
- The student whose ideas have always just been given by the last speaker
- The student who needs a helping hand

Handle error. When someone makes an error of fact, ask another question to let that person correct the error. If students are used to discussing points of disagreement, ask the group for a different point of view. Try to refrain from direct correction because it inhibits participation. When students become apprehensive, they begin to offer only answers they think the teacher or their peers will accept.

Remember that everyone has many "false" ideas that can be identified only if they are expressed. If students never open their mouths or write their thoughts, no one can discover what "right" and "wrong" ideas they have. Getting wrong ideas into the open is one advantage of discussion, but it won't happen unless the environment is safe and accepting. When it becomes clear that a large segment of the group misunderstands something, the teacher can plan activities to rectify these misunderstandings.

Listen attentively. One of the most difficult things for a facilitator or a group member to do is to listen—to really hear what is being said. Words do not always convey what a speaker intends. Furthermore, what one hears is often distorted because it is filtered through one's own thoughts and experiences. A facilitator must consciously listen to statements and help everyone understand them.

Listening may be passive and silent. Saying nothing shows acceptance. Keeping quiet and allowing students to say what they choose encourages them to say more. Nonverbal cues such as smiling and nodding show acceptance. Verbal clues such as "Uh-huh," "I see," and "Anything else?" show that you are listening.

Listening attentively may mean interacting with the speaker. The facilitator may rephrase information to clarify it or to gain insight into the true meaning of the speaker's statements. Such feedback tends to ensure understanding of what is being communicated.

Students must learn to listen to the facilitator's questions. A simple technique is to ask a question before naming the person who is to answer it. Students listen more intently when they may be called on:

- When we opened the pea pod, what did you find, Mary?

If the student's name is mentioned first, the other students can relax because they know that Mary must cope with the question:

- Mary, when we opened the pea pod, what did you find?

Facilitator Roles

The facilitative role most familiar to teachers is the role of directive facilitator. The role of the nondirective facilitator is less familiar.

The Directive Facilitator

The directive facilitator guides or leads members of a group to a predetermined point—for example, invention of a generalization. To be effective, a directive facilitator must know the content being investigated and must plan the progress of the discussion. This role is difficult for students to learn or to handle comfortably at this stage because they lack foreknowledge of the content to be discussed.

The Nondirective Facilitator

Many class discussions have no predetermined end point. Their purpose is simply to work with the unknown, to bring out as many ideas as possible—in short, to be open-ended. Such a discussion requires other leadership skills—those of the nondirective facilitator, one who encourages participation without guiding the direction of the discussion. This role requires the teacher to accept and trust students' ideas while keeping the discussion focused on a set topic.

The nondirective facilitator tries to elicit responses, to help generate data, and to develop values but does not give answers or impose values or interpretations. Instead, the nondirective facilitator helps the group to generate consensus, remaining neutral on matters concerning the group task. Like the directive facilitator, the nondirective facilitator wants every member's data and opinions to be included and accepted. The nondirective facilitator will employ some of the kinds of questions used by the directive facilitator, but the questions are more open-ended and offer less guidance.

Because the nondirective role does not depend on knowing content, it is easier for students to learn and practice than the directive role is. But students must have opportunities to learn leadership skills if they are to take responsibility for leading discussion. The nondirective role may be used by students when the class meets in small groups.

Guidelines for Leading Discussion

The following sections describe some techniques used by facilitators in directive and nondirective roles. First comes a set of guidelines for using questions to direct discussion and for helping a directive facilitator handle comments and responses to questions asked in a group. The directive facilitator should remember to accept all responses, encourage participation, support group members, and listen attentively. A second set of guidelines helps the nondirective facilitator prepare for and conduct open-ended discussions.

Guidelines for Using Questions to Direct Discussion

Beyond setting and maintaining a favorable social-emotional climate, the directive facilitator must keep the discussion moving in the desired direction. This can be done effectively with questions. But asking good questions takes planning and practice. Of the many kinds of questions that could be asked, some are appropriate at one point in a discussion but not at others. The effective facilitator knows how to ask good questions, what kinds of questions to ask, when to ask them, and what kinds of responses to expect.

The facilitator should decide beforehand what questions to ask. Writing them out helps to clarify direction and increase the likelihood of formulating clear, well-stated questions. The kinds of questions presented here develop content.

Clarifying questions. Asking for clarification is one way to respond to confusion. A clarifying question can elicit the meaning of unfamiliar terms or the rephrasing of disconnected, fuzzy statements to ensure common understanding. For example:

- Can you be more specific?
- What do you mean by "things"?
- Can you say that in another way?
- Can you give us an example?

Extending questions. An extending question pushes for elaboration. The facilitator may be probing for additions, analogies, alternatives, and explanations:

- Can you think of any other differences?
- Can you tell us some more about soil erosion?
- Is there anything else you would like to mention?
- Does heat have properties similar to those of any other thing you know?

Focusing questions. Focusing questions initiate discussion or shift its direction. Such questions are often prefaced by a summarizing statement:

- What we said we want to do first is analyze the data.
  Let's start by looking at the first two columns of the data sheet.
  Can anyone see anything common to both columns?
- Let's go back to our chart.
  How are these animals alike?

When a discussion goes off track, the facilitator may have to refocus it by repeating the question or writing it on the board. If anyone has misunderstood the question, the facilitator should reword it. The aim of refocusing is to get the discussion back to the topic:

- Now, what were we discussing a moment ago?
- How does that relate to the subject?
- What was the question we were discussing?

Lifting questions. Using questions to lift the level of discussion is a technique that facilitators often overlook or avoid. Such questions "lift" discussion by moving it from narrow to broad, from specific to general, from concrete to abstract.

The ability to seize opportunities for lifting the level of discussion reflects the facilitator's artistry. Lifting questions cannot be tailored to any one student because the direction of a contribution cannot be anticipated. But a question or a series of questions can help a student build a chain of reasoning that ends in a connection—an inference, a

hypothesis, a generalization, an explanation, a problem statement, or a definition. For example:

- Are heat and light connected in some way?
- From the two lists can you find a common property?
- Accepting that the properties listed on the board are common to both, what can we say about gases and liquids?
- What hypothesis might explain how winds form?
- How would you define life?
- What problem have we found in this?

Summarizing questions. When a person elaborates on an idea at length, its meaning gets buried. Then it is a good idea to ask for a succinct restatement or summary:

- How can we put what you have just stated on the board?
- Can you give us the main idea of what you are saying?

Using summary questions at the end of a discussion can make it an exciting and important part of a lesson. Such questions allow participants to discover the implications of what they have learned and to generate ideas and generalizations about what they have done.

Examples of Questions in Scientific Inquiry

Questions in an inquiry class can help students identify the problem to be investigated, stimulate them to form hypotheses, guide them in devising an experimental design, and help them analyze results of an experiment. The questions below are examples. Try to identify clarifying (C), extending (E), focusing (F), lifting (L), and summarizing (S) questions.

Questions for identifying a problem:

- ( ) What is puzzling about the phenomenon we are observing? What is happening here? How does this work?
- ( ) Which observations can you explain? Which ones can't you explain? What do you already know about this? What else is like this?
- ( ) What are the conditions under which this phenomenon is happening?
- ( ) How does your observation relate to your previous experiences? Have you seen something like this before?
- ( ) What do you know about this phenomenon? Does this remind you of anything else you have done?

Questions for stimulating formulation of hypotheses:

- ( ) How might this anomaly be explained?
- ( ) Do you know a related problem we have solved? Could you use it? Would it help solve this problem?

- ( ) What are some possible solutions to the problem or anomaly? Which solution seems the best or most reasonable to you?
- ( ) How might you separate this problem into simpler parts?
- ( ) How might you restate the problem to make it easier to understand?

Questions to guide design of an experiment:

- ( ) What are the variables? What are the points of change in this process?
- ( ) How might the variables in the experiment be controlled?
- ( ) What kinds of new data or information would support your hypothesis?
- ( ) What data do you need for finding a solution? What amount of data do you need for valid interpretation?
- ( ) What controls are necessary?

Questions for analyzing results of an experiment:

- ( ) Which data are relevant to the problem? Which data belong here? Which are unnecessary?
- ( ) How might you explain the data that contradict your hypothesis or your conclusion?
- ( ) Have you taken into account all necessary variables in testing your hypothesis? Did you check all the loopholes?
- ( ) What are the possible sources of error in the experiment?
- ( ) What are other possible interpretations of your data? How might someone else interpret your data?

Guidelines for Nondirective Facilitators

The following are tips for the nondirective facilitator to keep in mind when leading open-ended discussions.

Plan your strategy. Always plan your discussion strategy carefully and thoroughly. Think about where the group is heading or what it is attempting to do. List questions that will elicit what members know and how it connects with what they are trying to accomplish.

State the problem clearly and concisely. As soon as possible after the group convenes, try to get members to define the problem or question to be discussed. A sharply defined question helps to focus attention on the objectives. See that everyone understands the topic. Help the group clarify misconceptions.

Suggest a problem-solving approach. Ask for ways to address the issue, question, or problem. Solicit suggestions for ways to approach it. Get the group's acceptance of and commitment to a plan of action; then follow the plan. Consider midstream improvements if they are not disruptive or unreasonable. Use your judgment.

Accept and clarify communication. Try to accept all responses and statements because acceptance encourages members to contribute further. Relate one idea to another. Accept incomplete ideas. Ask for further development of the idea from the individual or the group:

- If I understand correctly, your idea would add to Ann's by . . .

Point out when a person's contribution is cut off and invite completion:

- I'm afraid we may have cut Karen off.
  Karen, do you have something you want to add?

Withhold judgment. The facilitator's way of responding to a question or statement can enhance communication or inhibit it. Judgmental responses—ones that reflect personal opinions and values—may show either approval or disapproval:

Approval: That's a great idea. I'm certainly glad you're in our group.
Disapproval: That wasn't a very smart thing to say.

Both kinds of judgmental statements suppress participation. Some members may hold back from fear of disapproval, others from fear of not getting approval.

Nonjudgmental responses—ones that do not reflect opinions or values—foster an accepting social climate within the group. Such responses may seek more information, acknowledge someone's feelings, or paraphrase content:

- When was the last time that happened?
- Is the lack of action frustrating you?
- In other words, do you think the data are questionable?

Accept feelings. Accept feelings along with content. When it seems necessary, clarify the feelings of a person or a group:

- Could you explain how you feel about that?

When conflict breaks out in a group, it often seems that a person rather than an idea is under attack. People tend to say "I don't agree with you" rather than "I don't agree with your *idea*." Thus feelings get confused with intellectual content.

The facilitator should try to interpret both the ideas and the feelings as objectively as possible:

- You feel frustrated? Uneasy? Confused?
- What is it about this *idea* you disagree with?

Facilitators should also accept their own feelings. Rather than venting emotion or exploding before the group, try to interpret your own feelings and state them as objectively as you can:

- I feel frustrated at not being able to progress more quickly.

Encourage other members to express their feelings in the same way.

Keep the discussion focused. When a discussion drifts from the topic, point it out and restate or paraphrase the original question:

- My understanding is that we were discussing . . .

Interrupt a long-winded speaker tactfully and invite others' contributions. If an important point is being neglected, get at it by asking such questions as these:

- Is there anything else that should be considered?
- Has anything been left out?

Summarize and clarify direction. Take time every so often to get the group to draw loose ends together. Get as fair and accurate a summary as possible. Call attention to unanswered questions:

- Are there any questions that are still unanswered?
- What should our next step be?

Give members time to discuss the implications of what was generated during the discussion. During the summary activity they should derive generalizations about what they have done. Close the discussion by having the group summarize its major accomplishments.

Techniques That Require Caution

Some techniques can have either positive or negative effects on interaction and discussion. Used prudently, these techniques can help the facilitator guide discussion and challenge members to think carefully about their responses. Used imprudently, these techniques can hinder interaction and destroy discussion. A facilitator should understand their effects and use them cautiously.

Verbal rewards. A directive facilitator sometimes uses verbal rewards both to support members and direct discussion. Within guidelines, verbal rewards can be effective in promoting discussion. The facilitator's tone is crucial because it can either encourage or impede participation. Verbal rewards like these are inappropriate:

T: What industries would we find in Honolulu?
S: Pineapple packing.
T: All right, what else?
S: Shipping.
T: Very good, Johnny! [You guessed what was on my mind.]

Such an exchange is likely to inhibit members who feel they are not good at guessing what is on the teacher's mind. It's better to avoid overrewards like these:

Excellent, Frank.
Wonderful!
Tremendous work!
Very good!

Overrewarding tends to impede rather than free the discussion. Some students are reluctant to respond, fearing they will not get the reward.

The most effective reward is implied acceptance of people and their ideas. In response to Johnny's answer, the facilitator could have asked "Any others?" with an encouraging look. Such a response keeps the possibility of discussion open, rewards the student by accepting the contribution, yet allows termination if the student adds nothing.

Verbal repetition. Repeating is a technique often used by discussion leaders. They repeat whatever anyone says:

T: What did you see?
S: A hawk.
T: A hawk. Did anyone see anything else?
S: A dove.
T: A dove. Did anyone see anything else?
S: A deer.

Repeating can facilitate discussion when it allows students to hear what has been said. Students often do not recognize the import of what they are saying unless they hear how it sounds. Repeating lets them hear it and lets others think about it too.

But repeating may reduce effectiveness. It can restrict interaction because all responses go through the facilitator. When the facilitator repeats everything, no one has to listen to anyone else.

If repeating limits good discussion, you can correct it in several ways:

- Refuse to repeat the response. Ask the person to say it again, as often as necessary, so everyone can hear.

- Accept the response without saying anything. Show openness to additional comments by using nonverbal cues.

- Instead of repeating, say "Anything else?" or "Any other comments?"

In discussion, students should talk to each other, not just to the facilitator. By making them initiate the ideas and questions that carry the discussion, the facilitator can evade directing the traffic of interaction.

Restricting words. Some words inadvertently restrict the openness of discussion. For example:

- What important things did the film show us?

Such a question puts members on the spot by making them guess what the facilitator considers important. Instead, the facilitator could ask,

- What did the film show you?

However, a restricting question can focus a discussion when students keep giving trivial or ill-considered answers. A restricting word produces a restraint that can be desirable or undesirable, depending on the circumstances.

To avoid using restricting words, write out your major questions ahead of time. Writing them lets you weed out restricting words beforehand, and it keeps you from throwing in restricting words when you ad lib.

Leading questions. A leading question suggests the answer the facilitator wants:

- It would be a good idea to pave that street, wouldn't it?
- Of course, the best way to do it is to walk to work, right?

Such questions can be used to direct discussion toward a desired end or to challenge students to think. Occasionally a leading question can stimulate discussion by forcing an incorrect or uncertain answer. Then members of the group can respond to the absurdity of the question. But leading questions should be used sparingly and cautiously because they tend to block discussion by loading the dice in favor of the answer the facilitator seems to want, leaving the facilitator in the dark about the authenticity of the answer.

Loaded questions. A loaded question traps a student:

- Have you stopped throwing chalk?
- When are you going to stop being so stubborn?
- Why didn't you check the temperature of the water?

No matter what, the student must deny the assumption or admit guilt.

Questions of this kind can perhaps make students think, but they are more likely to restrict discussion. They are trick questions that should be used only by an experienced facilitator.

Multiple questions. In their enthusiasm to stress the importance of a question, facilitators sometimes elaborate with more questions that may switch the focus from the original, intended question. For example:

- What was the substance that showed the most violent reaction? Which reaction produced the most heat?

Multiple questions often confuse group members. Writing questions ahead of time averts such mishaps.

Using "Wait Time"

In any discussion, the facilitator must allow the participants time to think. Many people find silence difficult to tolerate. Thinking can be slow and painful. But teachers can turn silence to advantage by waiting for a response. When a long silence ensues, support the student by saying something like this:

- Would you like to keep working on your problem or would you like someone to help you?

If the student decides to solve the problem alone, be sure to call for a response when the solution is reached. You can use the same tactic when a students says,

- I know what I want to say, but I can't say it.

Research by Mary Budd Rowe and others over the last decade has clearly shown the effects on the behavior of students and teachers in science classes when students are allowed time to think. Rowe found that the average amount of silent time a teacher let pass between question and response ("wait time") was just 1 second. Further, the average wait time between student response and teacher response or another question was only .9 second. The average inquiry science teacher asked three to five questions a minute, or up to 200 questions in one class period. This is inquisition, not inquiry.

Rowe found that increasing the wait time to 3 seconds had these significant effects on student behaviors:

- The duration of student responses increased.
- The number of spontaneous amending comments increased.
- The number of "no" and "I don't know" responses decreased.
- The number of tangential responses and responses that sound like questions decreased.
- The number of speculative responses increased.
- The amount of student-student comparing of data increased.
- The students made more inferences from data.
- The frequency of questions raised by students increased.
- The number of experiments proposed by students increased.
- The frequency of responses by students rated as lower achievers by their teachers increased.

Increases in wait time also brought important changes in the following teacher behaviors:

- Teachers became more flexible in their responses to students. They were more willing to accept diverse answers.
- Teachers' questioning strategies became more manageable. While the number of questions decreased, their variety and quality increased.
- Teachers raised their expectations for students who had been previously described as lower achievers.

When you ask a question and students just sit and look blank, relax. Wait and say nothing. Give them time to think by increasing wait time. If someone says "I don't understand," repeat the question or rephrase it for clarification without changing the focus. As Mary Budd Rowe says, "Inquisition is something teachers do to students. Inquiry is something teachers and students may do together." Allow time to think.

Summary

Teachers must play many roles in classrooms. One of the most important is facilitator of discussion. In this role, teachers must understand and practice leadership skills that establish and maintain participation and interaction. Different facilitator roles call for different techniques and require teachers to act in different ways. Facilitating discussion can be learned and can therefore be taught to students. Teachers who become conscious of what they do in facilitating discussion will be better able to help students develop good discussion skills.

Ask yourself these questions while shaping an inquiry discussion:

- Are my questions phrased simply and directly?
- Am I avoiding compound or multiple questions?
- Am I using an adequate mix of recall, processing, and applying questions?
- Are my questions extending and lifting the discussion?
- Are my focusing questions clarifying specific aspects of the investigation?
- Do some of my questions build cognitive conflict?
- Am I asking some comparative questions?
- Am I calling on a student after rather than before I pose a question?
- Am I allowing at least 3 seconds for a student's response?
- Am I accepting students' responses without prejudging or editing them?

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